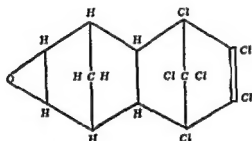

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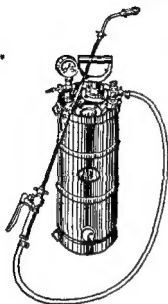
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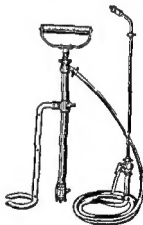
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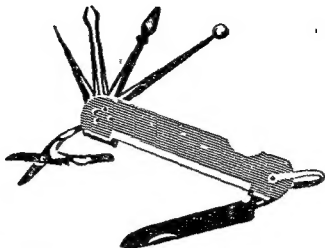
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FOREWORD

No other disease has had a wider prevalence or claimed a larger toll of life than malaria. Various theories about its causation were advanced from time to time, explored and exploded, till discovery by Ross in 1897, gave the world a full knowledge regarding the essential role of the female mosquito in the transmission of malaria. It is obvious that until the manner in which malarial transmission and endemicity were maintained in community was fully known, it was not possible to formulate a rational plan for preventing the spread of the disease. The necessity for the presence of plasmodium in the host and vector mosquito for the maintenance of malaria transmission has been proved beyond doubt. The carrier mosquito remains harmless in the absence of reservoirs of infection; nor is the infection in the host transmitted to another person in the absence of the vector mosquito. If malaria has been successfully controlled during the recent years, and today we are on the threshold of eradicating the scourge from vast tracts of the tropics, it is because of our intimate knowledge of the subtle ways of vector mosquitoes and the use of powerful insecticides that intercept the transmission cycles.

Ever since the importance of the mosquito as the carrier of malaria was brought to light, mosquitoes in general and the vectors of malaria in particular have been studied extensively. These studies have resulted in a fund of information about the habits of insects which form an important link in the epidemiology of malaria.

The difference in the behaviour of one species from that of another or the ways even of the same species in different environments are often striking. *A. culicifacies*, one of the most important malaria vectors in the rural parts of India is mainly associated with irrigated tracts, and breeds mainly in irrigation channels and waste irrigation water. *A. stephensi*, on the other hand is an urban carrier, breeding largely in wells and cisterns. *A. fluviatilis* and *A. minimus* breed in foot-hill streams, the former is an important vector in the foothills of South India, while the latter's role as a

vector is limited to the foot hills of the eastern Himalayas. The distribution of *A. sandaicus* is restricted to the salt lake areas of West Bengal, Orissa and Andhra States and appears to be gradually spreading southward.

The transmission of the malaria parasite being a direct result of the obligatory blood feeding habit of the female mosquito, is necessarily directly proportional to the degree of man mosquito contact. The increasing importance as a vector in U.P. Terai of *A. fluviatilis*, a species which had not been reported to be responsible for the transmission of malaria in this area up till a decade back, brings out clearly how changing environments can alter the feeding habits and thereby the vectorial status of a species. Another classical example is the clearing of jungles in Malaya as a measure to reduce breeding of *A. maculatus* which turned conditions more favourable for *A. umbrinus*, an equally important vector in that area.

In controlling malaria with the modern insecticides experience has shown that one has to be on the guard to avoid fresh hurdles that may crop up. It has been correctly pointed out that the victories against malaria in different parts of the world during the last decade would not justify complacency on the part of the governments of other malarious countries. It should be remembered that there can also be defeats. The development of resistance by the mosquitoes to insecticide has been observed by many workers. Fortunately such a phenomenon has not been encountered so far among any of the vectors of malaria in India. While planning for an all out drive against malaria, is being evolved to eradicate the disease before the mosquito becomes resistant, the epidemiologist and the entomologist have to keep a watchful eye to detect any reduction in the susceptibility of the mosquito to the insecticide, either physiological or behavioural.

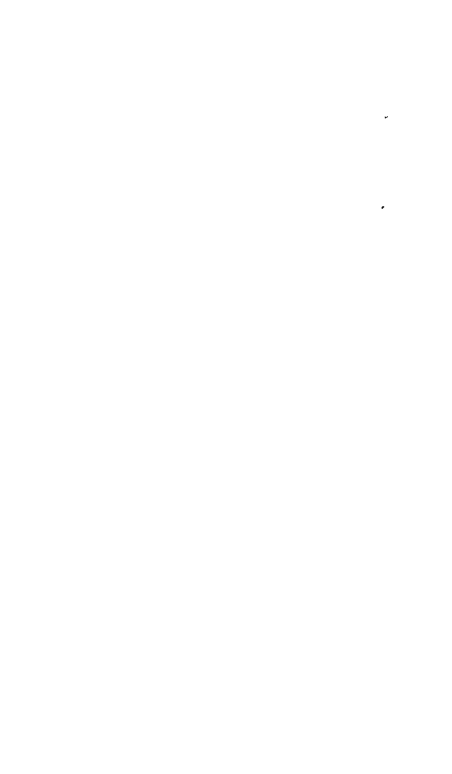
Though about twenty species of anophelines have been found infected in nature in India only the following species are of any real importance as vectors,

| | |
|-------------------------|--------------------------|
| <i>A. culicifacies</i> | <i>A. philippinensis</i> |
| <i>A. fluviatilis</i> , | <i>A. stephensi</i> and |
| <i>A. minimus</i> | <i>A. sandaicus</i> |

A review of the available information regarding the vectors in general and of the principal vectors in particular has been presented

in this volume. Most of the chapters have appeared as publications in the Bulletin of the National Society of India for Malaria and other Mosquito-borne Diseases. It is felt that such a compilation will be of immense value to the workers engaged in different parts of the country in the National Malaria Control Programme particularly when the goal is shifted to eradication of malaria from this subcontinent. Such a review of the present knowledge, apart from providing available information to the workers, serves to emphasize the lacunæ in our knowledge about the malaria vectors. Cautious planning of the control measures to suit local conditions and to effectively hit the local vectors, search for new knowledge regarding the subtle ways and adaptive modifications in the carrier mosquito, are expected to be stimulated by the present review.

—Editor



PICTORIAL ACCOUNT OF MALARIA VECTORS IN INDIA

BY

M. L. BHATIA

and

N. L. KALRA

(Malaria Institute of India, Delhi)

[June 12, 1957]

To a malarialogist out in the field some aid is essential in checking up the identity of a vector anopheline. An attempt has been made to do away with lengthy descriptions of morphology and present some notable morphological characters and diagrammatic representation of adult females in the accompanying pages to serve as a ready reckoner.

Anopheles annularis (Fig. 1) —Medium sized mosquito with predominantly dark general appearance, mesonotum covered with short pale scales, unspeckled legs, three hind tarsal segments completely white, V 3 extensively dark or at least dark spot at the point of bifurcation, some specimens show a dark band in the basal region of the third hind tarsal segment thus showing only two hind tarsal segments completely white.

A. philippinensis (Fig. 2) —General appearance very similar to *annularis* but with paler wings, closely resembles *pallidus*. Inner and outer prehumeral accessory dark spots on costa usually divided but in some cases basal third costa mainly dark, V 5 mainly pale as in *pallidus*, unlike *pallidus* sternopleura is usually devoid of scales, apex of hind tarsal segment 1 usually pale.

A. stephensi (Fig. 3) —Easily distinguishable species by its speckled legs, tips of hind legs dark and speckled palpi with two distal broad and one proximal pale bands, mesonotum with obvious scales.

A. sundavicus (Fig. 4) —Ornamentation resemble that of *subpictus* from which it is easily separable by the speckled legs, has a superficial resemblance to *stephensi* but is at once distinguishable by palpi being unspeckled and having one apical broad and two sub-apical narrow white bands, mesonotum with hairs or narrow hair like scales.

- A. fluviatilis* (Fig. 5) —Small to medium sized comparatively dark mosquito, palpi with three pale bands, the dark band between the apical and sub-apical pale bands 4 to 5 times the length of sub-apical pale band. Mesonotum pale medially, dark brown laterally. Inner quarter costa continuously dark; no fringe spot at V. 6, tarsi all dark or with very faint banding.
- A. minimus* (Fig. 6) —Closely resembles *fluviatilis*, but characterised by palpi with two broad apical pale bands, intervening dark band usually about as wide as either of the pale bands, rarely exceeding twice the extent of a sub-apical pale band. Proboscis may be dark or have small flavescent area ventrally in the distal half. Inner quarter costa with a pale interruption or an indication of this on at least one wing.
- A. varuna* (Fig. 7) —Resembles *minimus* from which it can be differentiated by inner quarter costa without any pale interruption or any trace of it, distal half proboscis usually shows faint or sometimes marked flavescence.
- A. jeyporiensis* var. *candidiensis* (Fig. 8) :—Small to medium sized mosquito, mesonotum covered with narrow whitish scales, base of anterior forked cell is slightly nearer the wing base than that of the posterior forked cell. Wings with presector humeral pale spots, narrow pale apical bands on tarsi present. There are three pale bands on palpi, the apical ■ broader than the other two pale bands. In the type form the sub-apical black band is 4 to 5 times the length of the sub-apical pale band but in the variety *candidiensis* the sub-apical black band is equal or slightly broader than the sub-apical pale band.
- A. leucosphyrus* group (Fig. 9) —Medium sized mosquito with narrow pale bands on palpi, proboscis dark, wings with multiple small dark spots on a number of veins, particularly V. 3, V. 5 and V. 6, legs speckled, a wide white band at the tibio tarsal joint of hind legs, fore tarsi apically and basally banded, hind tarsi apically banded and tip of last segment pale.
- A. culicifacies* (Fig. 10) —Small to medium sized mosquito with culex-like attitude when resting in living state, palpi are dark with narrow pale bands including that at the tip, mesonotum without scales, wings with a dark spot on V. 1 under the pale interruption (humeral) on inner quarter of costa, V. 3 all dark, legs dark and tarsi usually unbanded.

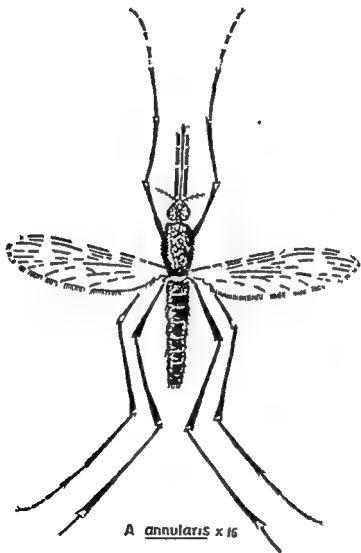
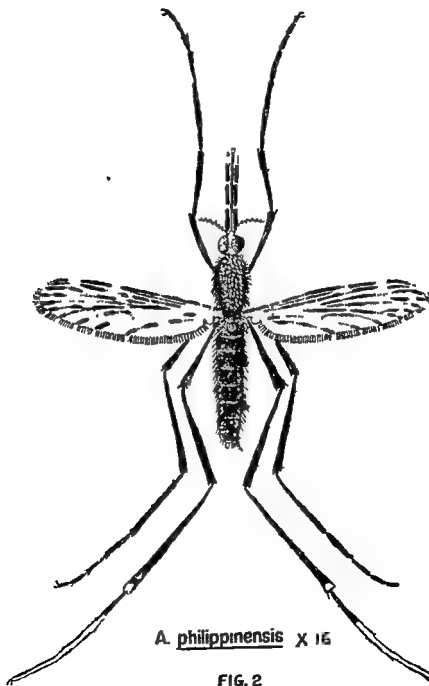


FIG 1



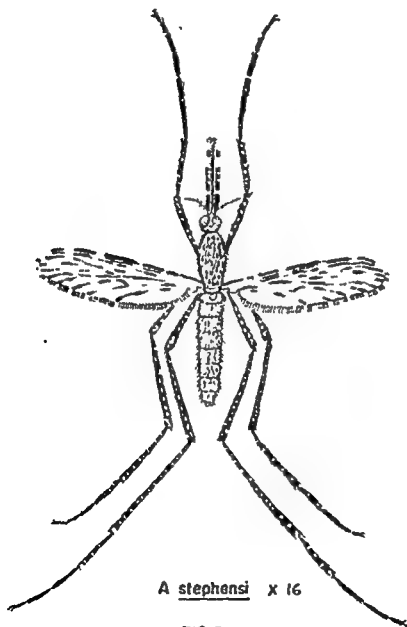
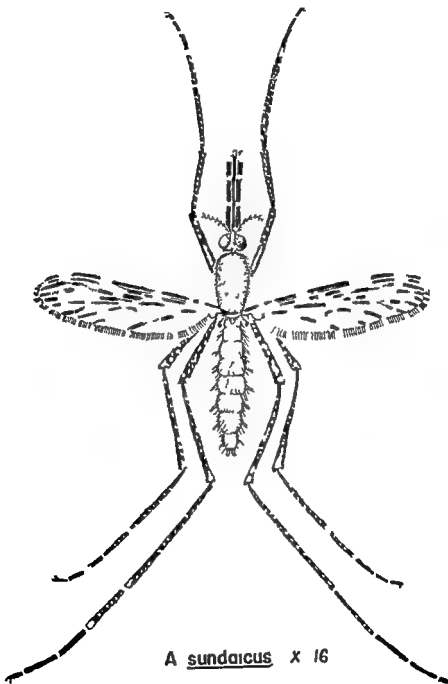


FIG 3



A. sundaricus x 16

FIG 4

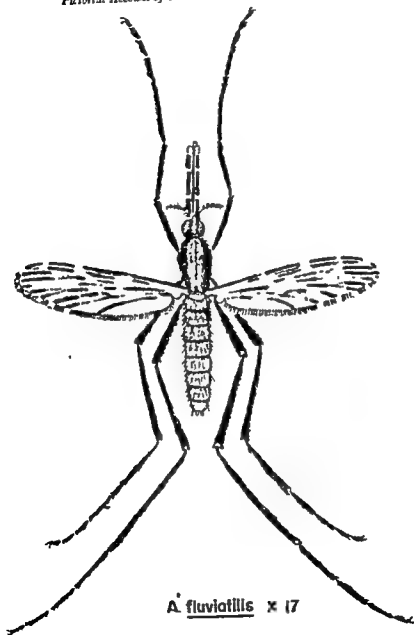
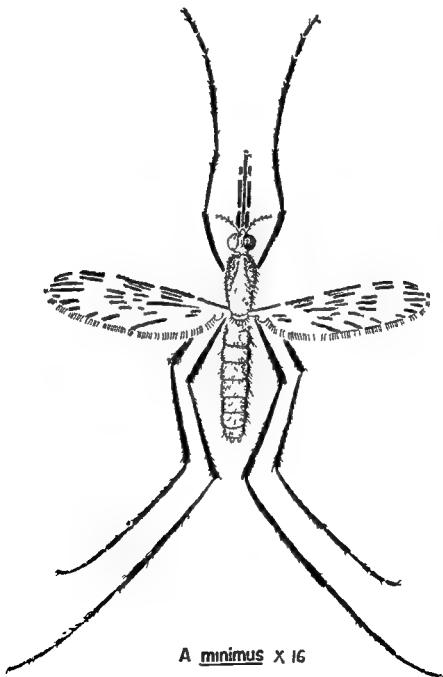
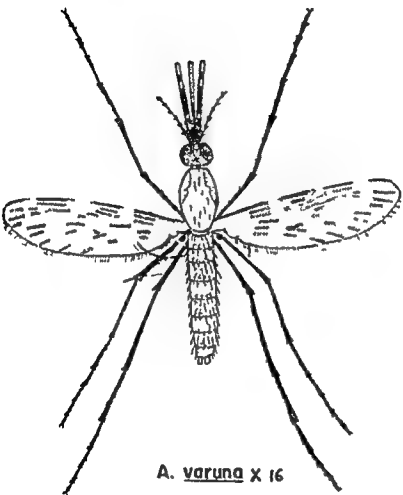


FIG. 5



A. minimus X 16

FIG 6



A. varuna X 16

FIG. 7

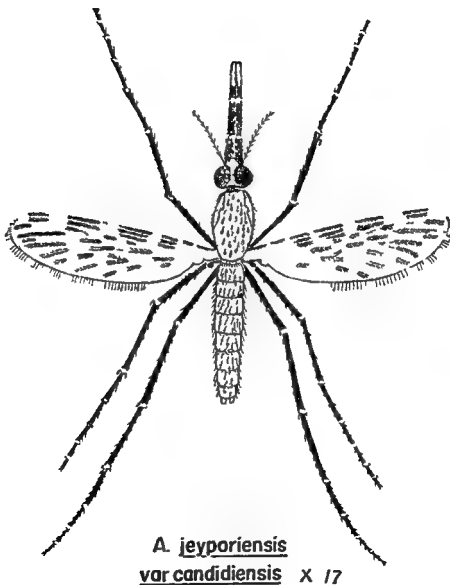


FIG 8

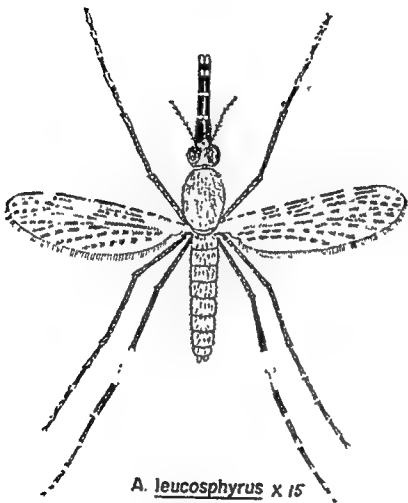
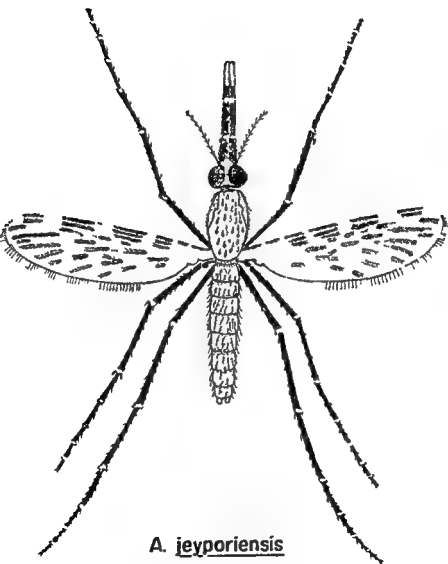
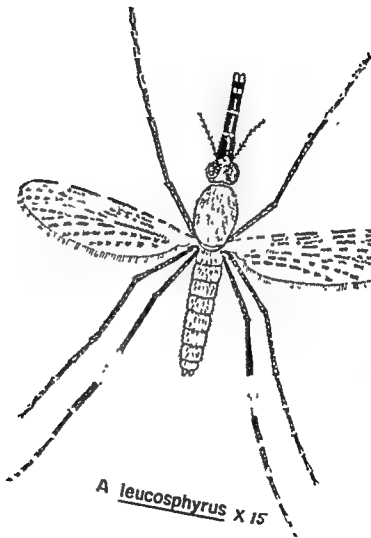


FIG. 9



A. jeyporiensis
var candidiensis X 17

FIG 8



A. leucosphyrus X 15

FIG. 9

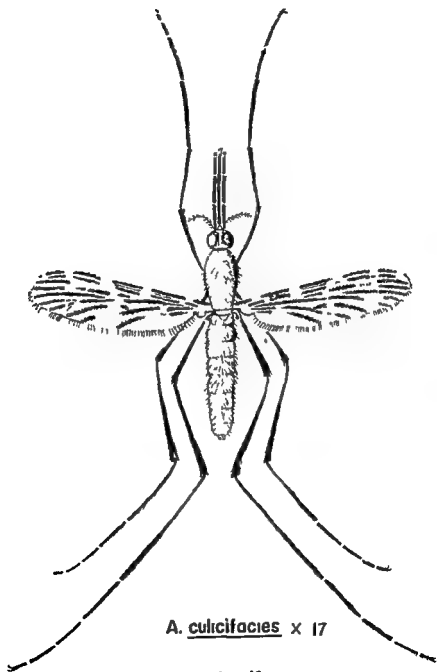


FIG 10

I. *A. ANNULARIS* VAN DER WULP, 1884

BY

V. VENKAT RAO

[July 7, 1954]

TILL about 1930, *Anopheles annularis* was known in India as *A. fuliginosus*. Its extra dark band on the apical segment of the palpi, was described in 1904 as variety *nagpuri* while that with an extra dark band on the hind tarsus, giving only two segments continuously white as var *adiei*. Both these are only melanic variations, the latter being usually seen as a winter form (Christophers, 1933).

Though *A. annularis* is not important as a malaria vector in India as a whole, it has considerable local importance over a large area in the Orissa Coastal Plain, where it maintains hyperendemic conditions. In certain areas, it plays a secondary part in malaria transmission and is sometimes responsible for severe epidemic outbreaks.

DISTRIBUTION

A. annularis has a very wide distribution in India¹ and in the Far East. It is found almost everywhere in India, from Nepal in the north to Travancore in the south and from Assam in the east to Bombay in the west. Outside India, it has been recorded from Pakistan (both east and west), Philippines, Formosa, South-China, Borneo, Java, Sumatra, Indo-China, Malay Peninsula, Thailand, Burma, Ceylon and Little Sunda Islands.

BREEDING PLACES AND HABITS

The preferred breeding places of *A. annularis* are clean weed-grown stagnant waters, notably margins of lakes, tanks, moats, dead rivers, swamps, borrow pits and ricefields. Sometimes, it is also found in large canals with vegetation and in grassy edges of slow-running streams (Christophers, *loc. cit.*). Studies by Sen (1941) and Senior White *et al.* (1943) in Bengal and Orissa respectively have shown that, while *A. annularis* is capable of breeding

¹ Chiefly in the plains but also in the hills up to 7000 feet.—*Eds. br.*

in a large variety of waters, the vast bulk of the breeding takes place in large weed choked tanks, ponds and borrowpits on the one hand and in ricefields on the other. Senior White found that borrowpits tanks and ricefields were responsible for 93.8 per cent of the total *annularis* output at Bhadrak and 98.4 per cent at Khurda Road. Even where the tanks and borrowpits were clean-weeded at regular intervals as at the above two stations 67 per cent of the total larval output was found in them against about 27 per cent in ricefields.

The tanks and ponds of Orissa and Bengal are overgrown with aquatic phanerogamic vegetation to a much greater extent than anywhere else in India. In Orissa Senior White and others identified from these waters 43 species of aquatic plants, not all of which were however, favourable for *annularis* breeding. Working in Bengal, Sen (*loc cit*) observed that *Hydrilla verticillata* and *Ceratophyllum demersum* were especially associated with *annularis*. In Orissa in addition to these two species *Nymphaea lotus*, *Nelumbium cristatum* and *Salvinia cucullata* had also been found associated with *annularis*. On the other hand, certain plants like *Lemna minor*, *Lemna polyrrhiza*, *Wolffia arrhiza* and *Eichornia speciosa* were found unfavourable and even appeared to have an inhibitory effect. The breeding in ricefields is often associated with the presence of filamentous green algae mainly *Spirogyra*. In hill tracts however, where tanks ponds and borrowpits are scarce, larvae are found in the grassy edges of slow running streams and rain-fed ricefields but their output is probably very low.²

A *annularis* is mainly a fresh water breeder, but on a few occasions, Venkat Rao and Ramakrishna (1947) observed profuse breeding along the margin of the Chilka Lake in South Orissa, at a time when the salinity of the lake water was 600 parts per 100 000.

Muirhead Thomson (1951) has shown that the temperature of stagnant waters like tanks and ricefields in Assam was about 41°C (106°F) at a time when the temperature of water in grass-edged streams seldom exceeded 34°C (90°F). The marked preference of *annularis* to stagnant waters, therefore, indicates that,

² Borel (1926) in Indo-China found it breeding in tree holes and cut bamboos. Walch and Soesilo (1927) recorded them in saline water in Java.—Editor

the aquatic stages develop best in waters with a relatively higher temperature or at least that the flora favoured by them are present in quantity under such conditions

It may be stated in general that the breeding of *annularis* is profuse in areas with large bodies of stagnant water and vast stretches of ricefields, where these are limited, *annularis* is for all practical purposes insignificant

ADULT HABITS

Resting places — Quoting a number of observers Christophers (*loc cit*) concluded that in India *annularis* was pre-eminently a cattle feeding species being commonly found in very large numbers in cattlesheds and such like situations³ Senior White *et al* (*loc cit*) also found the average ratio in human habitations and cowsheds as 1 : 3. They also observed that the maximum number in human habitations occurs frequently in August and September and the maximum in cowsheds in October and November and that the large autumnal production overflows into cowsheds more than into human habitations. In cowsheds made of thatched roofs with or without mud or bamboo walls *A. annularis* rests to an appreciable extent in the inaccessible layers of the thatch and it has been found that in collections by hand only about two-thirds of the resting adults are captured. The per-man hour collections made by hand catching are thus likely to yield only incomplete information about the actual *annularis* prevalence.

The out door resting habits of *annularis* have been very little studied in India. While working on out door resting anophelines Senior White (1946) was able to collect only one specimen of *annularis* resting on the bank of a stream but his observations were carried out in hill tracts where prevalence of *annularis* is negligible.⁴ More observations have however been carried out in Burma. The Gyaw (1927) recorded that, from June to October, adults of this species could be found resting during the day in scrub jungle around their breeding places in Northern Burma. Fox (1950) quoted Feegrade's observation that though adults could be seen feeding on cattle at night, there were none in human habitations or cowsheds during the day. He also added his own observations that in the

³ Collected from among bushes. Grass etc. away from habitations (Christophers 1911) — Editor

Mandalay-Maymyo foothills, while 298 adults were captured in night collections, not a single specimen was found resting by day in human habitations. These facts indicate that *annularis* in Burma rests more in outdoor shelters and is thus somewhat scarce in day time collections from either human habitations or cowsheds.

Feeding time—The author's observations made in a student's hostel at Chatarpur (Ganjam District, Orissa) show that *annularis* enters the house for feeding during the second quarter of the night and that most of the feeding is completed before midnight. Occasionally, however, they are found feeding at or shortly after sunrise.

Food preferences—There is no doubt that *A. annularis* is mainly a zoophilous mosquito. Senior White (1947) dealing with Orissa Coastal Plain where *annularis* is a vector and the Central Provinces where it is not remarked that in both the areas the anthropophilic index is so low that *prima facie* it appears inconceivable that it should play any part in malaria causation. The anthropophilic indices of house and cowshed resting specimens in these areas are shown in Table I.

TABLE I
Anthropophilic indices of *A. annularis*

| Area | Houses | | | Cowsheds | | | Totals | | |
|----------------------|--------|-----|-----|----------|-----|-----|--------|-----|-----|
| | No + | M + | A I | No + | M + | A I | No + | M + | A |
| Orissa Coastal Plain | 281 | 10 | 3.6 | 553 | 1 | 0.2 | 834 | 11 | 1.3 |
| Central Provinces | 148 | 3 | 2.0 | 466 | 8 | 1.7 | | 11 | 1.8 |

M+ = positive for man No + = number positive

A I = anthropophilic index per cent

Though precipitation tests were not carried out for *annularis* in Burma, night collections, as reported by Fox, were made while mosquitoes were actually feeding or about to feed, which tend to conform the Indian workers' observations on the zoophilic habits of this species.

Fox (*loc cit*) concluded on the basis of available evidence that, under normal conditions, *annularis* feeds mainly on cattle and that,

if cattle are not available, it will readily feed on man. He also quoted Macan ■ stating that *annularis* feeds on man-out-of doors too, if cattle are absent.

Gonotrophic cycle —It was observed in a large number of cases that during July to November, when *annularis* prevails in large numbers, the gonotrophic cycle, is completed in 48 hours. However, during the late rainy season and the autumn about 20 per cent of mosquitoes, are observed to require two or more feeds to mature a single batch of eggs. The interval between the first feed and oviposition may in such cases extend to six or even eight days. This condition, described as 'Gonotrophic disordance'" (Venkat Rao, 1947), has been observed also in *A. culicifacies* in the Central Provinces. The same condition has since been observed in *A. flutifilis* in South India by Jaswant Singh and Mohan (1951).

Swarming and mating —In India, despite the immense amount of work which had been carried out on the rich anopheline fauna up till about 1937, no observations had been made on swarming of *Anopheles* (Muirhead Thomson, *loc cit*). The first of such observations in nature were made in respect of *A. annularis* and *A. subpictus* by Ramachandra Rao and Russell (1938), which were followed by those on *A. subpictus* by Venkat Rao *et al* (1942). Subsequently the present author observed swarming of males and females of *annularis* at Gangadharpur in Orissa, the same village where observations were earlier made on *sundaeus* and *subpictus*. At the time, there was profuse breeding of *annularis* in the saline water of the Chilka Lake, whereas no such breeding was taking place elsewhere near the village ■ the ricefields had dried up and the fresh water tanks and ponds were under regular clean weeding and paris green treatment. At about 5.30 p.m. (Indian Standard Time) in March 1946 a large swarm of mosquitoes was observed about six feet from the ground level not far from the Chilka Lake. They were all *annularis*, both males and females. Copulating pairs were also observed in the swarm. Walking away from the Lake, the swarm was observed in an almost unbroken line for nearly half-a-mile, beyond which it gradually thinned out. It will be of interest to note that *sundaeus* and *subpictus* swarms took place well away from

4 Sen & White (1951) dealing with this phenomenon observed in a number of species *A. aquasilis*, *A. subvarius* and *A. normani* and remarked that the strictest lock gonotrophic concordance appears to be the exception rather than the rule in several *Anopheles*.

the Lake, on the elevated platform of the railway station, which was at least 20 feet above the level of the Lake, whereas the *annularis* swarm was observed at a lower level of only five feet or so above the Lake and not beyond that altitude

Flight range—Christophers (*loc cit*) remarked that *annularis* "is a powerful flier", covering considerable distance from its breeding places and may be seen darting rapidly, when disturbed during the day, among bushes etc⁵

Hibernation—There is, of course, no true hibernation among *Anopheles* in India but, during winter, there is an appreciable reduction of *A. annularis* density in Orissa,⁶ though breeding places are still found in abundance. However, the winter form with the extra dark band on the apical segment of the palpi is observed to come up in small numbers, not only in the Central Provinces where the temperatures are low in winter, but also in the Ganjam District of Orissa where the winters are very mild.

Longevity—Very little study has been made of the longevity of *annularis*, either under laboratory conditions or by field trials. It is generally well known that, though all anopheline species are potential vectors many of them do not take any active part in transmission in nature because of their feeding habit, lack of sufficient contact with man or inability to survive long enough to complete the sporogonic cycle. Perhaps *A. annularis* belongs to the last category. However, Senior White *et al* (*loc cit*) calculated, by the relative prevalence of larvæ and adults, that the longevity of this species increases during September, October and the first half of November, when there is increased urge to feed on man and when only infective specimens are encountered. On account of gonotrophic discordance observed by Vankat Rao (1947) the mosquito is fixed in houses (or cowsheds) for prolonged periods whereby it is not exposed to the natural hazards incidental to outdoor existence. It thus appears that, in nature, *annularis* acquires greater longevity during September-November, than at other periods of the year.

5 Anti larval treatment of breeding places situated within a radius of half a mile from the periphery of habitations can result in efficient malaria control among the inhabitants

6 *A. annularis* is a winter species in Delhi State—Editor

RELATION TO MALARIA

A. annularis is a vector of importance mainly in the Orissa Coastal Plain of the Indian region, where hyperendemic conditions are encountered. Though some infective specimens have been found in Bengal, they are not thought to be of real significance there owing to the more efficient vector, *A. philippinensis* dominating the picture.⁷ In the coastal plain of Orissa, Senior White *et al* (*loc cit*) dissected 9,183 specimens and found only 14 gut infections and 7 gland infections, giving a total infection rate of 0.23 per cent and a sporozoite rate of 0.08 per cent. They consider that transmission is possible under these conditions mainly because of the enormous density of this species, which is sometimes as high as 64 per man-hour in human habitations and 158 in cattlesheds. The presence of sporozoite infections as observed by Senior White *et al* (*loc cit*) is probably due to gonotrophic discordance, as such mosquitoes are not obliged to fly out frequently for oviposition and are fixed at the feeding place for prolonged periods. In areas however where climatic conditions are different from those in Orissa, and therefore gonotrophic discordance does not prevail *A. annularis* is harmless as a malaria vector. Outside the coastal plain *A. annularis* with the sporozoite rate of 0.08 per cent but with much lower densities is shown to be a secondary vector as in Puri Town (Orissa), where *A. sundicus* is the primary vector (Panigrahi, 1942). A few infections have also been found in this species around the Chilka Lake by Sarathy (1932) and on the North Madras Coast by Ramakrishna (Senior White *et al* 1947) but it is thought that *A. annularis* plays a minor and not very significant part in transmission there. In these areas it always exists along with *A. sundicus*. Severe epidemics are sometimes found superimposed on hyperendemic conditions in the Coastal Plain as well as in those restricted localities in the same area where there is a milder degree of malarial endemicity. These however, are localised and occur at irregular intervals of five to seven years.

According to Fox (*loc cit*) *A. annularis* is an important vector on the Arakan Coastal Region of Burma out of 1,315 specimens dissected from that region three gut infections and seven gland

⁷ *A. annularis* has also been recorded as a vector in Assam by Ramakrishna. Infective specimens of *A. annularis* have been reported by Dr. P. S. Sanyal in his paper in *Indian J. Med. Res.* during August and September 1951. *A. annularis* has also reported infective specimens from *Testes* (regular).

infections were found, giving an infection rate of 0.07 per cent and a sporozite are of 0.05 per cent. These infection rates are lower than those recorded in India but there too transmission is probably dependant upon heavy densities of the vector. In this region also, *annularis* co-exists with *A. sundacus* but curiously enough no infections were found in the latter species and, therefore, *annularis* has to be considered as the major vector, with *A. sundacus* playing a secondary part. Fox also quotes Robertson as recording six 'infections' out of 392 dissected (infection rate 1.5 per cent) on the Burma-China border in Western Yunnan, where *A. minimus* is the principal vector.⁸

CONTROL

Anti larval measures against a prolific breeder like A. annularis are likely to be very difficult in rural areas. As the breeding occurs in both weed choked stagnant waters and in ricefields, chemical larvicides like oil and paris green are liable to be very costly and, sometimes owing to unfavourable weather conditions, ineffective as well. Biological measures like clean-weeding were tried on a large scale by Senior White *et al* (1943) and Venkat Rao and Ramakrishna (1947) and observed to be effective against *annularis* but they were tried at a time when labour was cheap enough to compare favourably with chemical treatment. At present, owing to greatly increased cost of labour, such measures are not likely to find favour with either malarialogists or administrators. Paris green treatment of ricefields is beset with difficulties, not the least of which is the oppositions from rice growers who are perhaps needlessly afraid of damage to the crop. Venkat Rao (1942) has shown that *annularis* breeding in ricefields can be effectively controlled by stocking them with sullage during the dry season (or by a liberal use of organic manures like compost) but this presupposes a high level of agriculture which is yet to be attained.

As the transmission is restricted to four months only from August to November each year, the best method of control would be to spray all houses and cowsheds with DDT at the rate of 100 milligrammes per square foot in a single dose during June July. The per capita cost of such spraying does not exceed six to eight annas,

⁸ Tyssal Jones (1950) considers *annularis* as the principal vector in Kyaukpyn Ramree island in Burma.—Editor

which is well within the financial capabilities of any community [Effective control of this species by DDT residual spray has been obtained in mud plastered houses in Orissa (Hajra 1948 Adhikari and Ganguli 1949) The dosage used was 38.50 mg per sq ft and its residual effect lasted for 6-8 week —Editor]

In large towns like Cuttack and Berhampur where the population is high and breeding places are relatively limited clean weeding of stagnant waters coupled with improved methods of rice culture specially in the immediate vicinity of towns is likely to result in effective control of malaria there It is realised that these towns are not endemic for malaria but are subject to periodical epidemic outbreak however, continued work specially in the inter epidemic periods may be found to be advantageous in warding off and even eliminating such outbreaks

REFERENCES

- Christophers S R (1933) *The Fauna of British India* Vol IV
Taylor & Francis London
- Adhikari A K and Ganguli N (1949) *Ind J Mal* 3 p 137
- Fox D G R (1950) *The anopheline mosquitoes of Burma*
Thesis Photostat Copy
- Hajra B N (1948) *Ind J Mal* 2 p 307-311
- Jaswant Singh and Mohan B N (1951) *Ind J Mal* 5 p 513
- Murhead Thomson R C (1951) *Mosquito behaviour* Edward Arnold
London
- Panigrahi M G (1942) *J Mal Inst Ind* 4 p 423
- Ramachandra Rao T and Russell P F (1948) *ibid* 1 p 395
- Sarathy M N P (1932) *Ind Med Gaz* 67 p 254
- Sen P (1941) *J Mal Inst Ind* 4 p 112
- Sen or White R (1946) *ibid* 6 p 425
- Idem (1947) *Ind J Mal* 1 p 111
- Idem (1951) *ibid* 5 p 465
- Sen or White R, Adhikari A K, Ramakrishna V and Roy B B (1943) *J Mal Inst Ind* 5 p. 159
- Sen or White R, Ramakrishna V (1947) *Ind J Mal* 1 p 81
- and Venkat Rao V
- Sen or White R and Venkat Rao V (1946) *J Mal Inst Ind* 6 p 411
- Tha Gyaw (1927) Printed Report Office of Director
of Health Services Burma
- Venkat Rao V (1942) *Ind Med Gaz* 78 p 214
- Idem (1947) *Ind J Mal* 1 p 43
- Venkat Rao V and Ramakrishna V (1947) *ibid* 1 p 51
- Venkat Rao V, Roy B B and Jagannathan Rao B (1942) *J Mal Inst Ind* 4 p 40,

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REFERENCES

- | | |
|---|--|
| Christophers, S. R. | (1933) <i>The Fauna of British India</i> Vol IV Tavlor & Francis London |
| Adhikari A. K. and Ganguli, N. | (1949) <i>Ind J Mal</i> 3, p 1-37 |
| Fox, D. G. R. | (1950) <i>The anopheline mosquitoes of Burma</i> , Thesis Photostat Copy |
| Hajra, B. N. | (1948) <i>Ind J Mal</i> 2, p 307-311 |
| Jaswant Singh and Mohan B. N. | (1951) <i>Ind J Mal</i> 5, p 513 |
| Muirhead Thomson R. C. | (1951) <i>Mosquito behaviour</i> Edward Arnc. l, London |
| Panigrahi, R. G. | (1942) <i>J Mal Inst Ind</i> .4, p 423 |
| Ramachandra Rao, T. and Russell, P. F. | (1958) <i>Ibid</i> , 1, p 395 |
| Sarathy M. N. P. | (1932) <i>Ind Med Gaz</i> ,67 p 254 |
| Sen P. | (1941) <i>J Mal Inst Ind</i> ,4 p 112 |
| Senior White ■ | (1946) <i>Ibid</i> .6, p 425 |
| Idem | (1947) <i>Ind J Mal</i> ,1, p 111 |
| Idem | (1951) <i>Ibid</i> 5, p 465 |
| Senior White, ■, Adhikari A. K., Ramakrishna, V. and Roy B. B. | (1943) <i>J Mal Inst Ind</i> .5, p 159 |
| Senior White, R., Ramakrishna V. and Venkat Rao, V. | (1947) <i>Ind J Mal</i> ,1, p 81 |
| Senior White, R. and Venkat Rao, V. | (1946) <i>J Mal Inst Ind</i> ,6, p 411 |
| Tha Gyaw | (1927) <i>Printed Report</i> Office of Director of Health Services, Burma |
| Venkat Rao V. | (1942) <i>Ind Med Gaz</i> 78, p 214 |
| Idem | (1947) <i>Ind J Mal</i> ,1 ■ 43 |
| Venkat Rao, V. and Ramakrishna V. | (1947) <i>Ibid</i> ,1, p 51 |
| Venkat Rao, V., Roy B. B. and Jagannathan Rao, ■ | (1942) <i>J Mal Inst Ind</i> ,4, p 402 |

II. *A. philippinensis* LUDLOW, 1902

BY

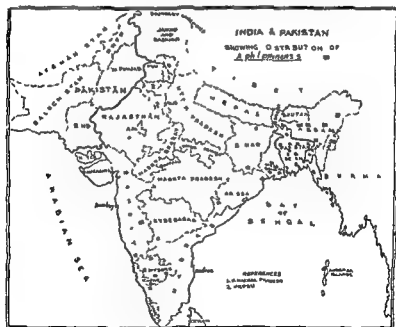
K. S. KRISHNAN

(Malaria Institute of India, Delhi)

[June 6, 1953]

DISTRIBUTION

A. philippinensis has a wide distribution in the Indian sub-continent (Map 1)—Assam, Bengal, Bihar, Bombay, Deccan, Konkan, Madras Coast North, Malabar, Mysore, Orissa, and Andamans. Outside India it is found in Burma, Thailand, Indo China, South China, Sumatra, the Philippine Islands, Borneo and New Guinea.



Map 1

BREEDING HABITS

The favoured breeding places of *A. philippinensis* are tanks, pools, and ditches. Christophers (1912) and Covell (1927) found this species breeding in ricefields in the Andamans. Sen (1935, 1948 a and b) recorded *philippinensis* breeding in ricefields in Bengal

but the numerical incidence was low. He attributed this restricted breeding in ricefields to two factors (a) the absence of green algae—*Spirogyra*—from ricefields due to increase in shade when the rice plants grew to a height of $2\frac{1}{2}$ feet and postulated a very close association between *philippinensis* breeding and *Spirogyra*, (b) it was also found that the temperature in ricefields reached 42°C or more and it was beyond the tolerance limit of the species. But Krishnan (1940) in Bengal found no larvæ in ricefields. Iyengar (1944) too did not find any larvæ of *A philippinensis* in ricefields in Mymensingh. Breeding in borrowpits in Bengal was practically negligible (Iyengar, 1944).

Ramsay and Macdonald (1936) found *philippinensis* breeding in permanent pools with vegetation and light shade. Iyengar (1944) reported that this species liked ponds exposed to sunshine containing water with high dissolved oxygen content and bred in clean waters and were absent in waters even with the slightest trace of sewage or organic contamination. Intense breeding was found to take place in water with thick growth of submerged vegetation particularly *Hydrilla verticillata*, *Ceratophyllum demersum* and certain species of *Utricularia* and *Najas*. Duckweeds and water hyacinth were not suitable for they cut off sunlight and thereby brought about changes in plankton in the water. Certain types of green algae which thrived well in sunlight were favourable to the breeding whilst certain other algae like *Cyanophyceæ* and the blue green algae (e.g. *Anabaena* and *Oscillatoria*) were inimical. *Euglena* was also unfavourable. There was such close association of breeding of this species and the type of vegetation which made Bose (1931) hold to state he could attract or repel this species from village tanks by introducing or removing suitable vegetation. The prevalence of *philippinensis* is dependent on the depth of subsoil water (Iyengar 1942). He found that if the level of the water table is low the density of the species is high and vice versa. The seasonal prevalence of this species in Bengal is July to October (Iyengar 1944).

BIONOMICS OF ADULTS

(a) *Adult resting places*.—In Bengal *philippinensis* has been found resting mostly in human habitations (Timbers 1935, Krishnan 1940 and Iyengar 1944). Ramsay and Macdonald (1936) found in Assam the adult resting in equal numbers in cattle sheds and houses

while in Bengal the preference was more to the houses Ganguli (1947) found in Bengal-Orissa border (between Balrampur and Rupsa) that adults were resting only in houses and in two years search no specimen was collected in cattlesheds while the number collected in houses was 276

Iyengar (1944) found that the adults usually rested on the wall within 1½ feet of the floor inside houses Ganguli (*loc cit*) could not confirm this finding but observed that *A. philippinensis* rested in the day time on the walls of dark room from about four feet above the floor, hanging clothes umbrellas, etc., and were not found too near the floor Reid and Wharton (1949) in Malaya found 454 *philippinensis* adults resting out of doors during day time in a rubber estate in a total collection of over 1,600 anophelines

BITING TIME

In Bengal, the adults were mostly noted to feed from 8 to 10 p.m. and 2 to 4 a.m. In Malaya, they were found to feed throughout the night and the majority did not commence feeding until after 9 p.m. (Reid and Wharton, 1951) Wharton (1950) observed that *philippinensis* entered huts after 9 p.m. After feeding they went to the grass outside the sheds and many of them rested there till dawn Macan (1950) in Arakan region reported that this species attacked people out of doors He also observed that *A. philippinensis* showed a small biting peak round about midnight and a main peak between 03.00 and 04.00 hrs. The same author (Macan, 1948) while working in the Rabaw and Kale valleys in Burma found the peak of biting intensity between 22.30 and 23.00 hrs. and thereafter a marked falling off, a second peak between 01.00 and 01.30 hrs. and biting continued at a reduced rate from then until dawn

ANTHROPOPHILIC INDEX

The precipitin tests carried out are very few and the only published records are from Assam by Ramsay and Macdonald (1936) where the anthropophilic index noted was 6.4 in 343 specimens tested, and in Malaya the index was zero per cent in a test conducted on adults caught from outdoors (Reid and Wharton, 1949)

FLIGHT RANGE

No information direct or indirect is available regarding the flight range

SURVIVAL OR LONGEVITY

Green (1934) reported that the mean survival time of *A philippinensis* in Malaya was 48 days with a range of 4 to 62 days, under laboratory condition

SWARMING

Swarming of *A philippinensis* was regularly observed in Malaya. It commenced 10 to 15 minutes before complete darkness and followed normal patterns except that swarming site did not appear to bear any relation to specific objects such as bushes (Reid and Wharton, 1949)

RELATION TO MALARIA

A philippinensis is a very important vector in Deltaic Bengal. Natural infection of this species has been reported from Burma but it is not considered an important carrier there. The dissection records so far available are given in Table I

Iyengar (1940) reported that the infection rates were high during the period September to January and no infection was found during March and April. The high infection rates recorded during the period September to November conform to the generally accepted view that transmission of malaria in Bengal is most frequent following the monsoon. Sen (1948 b) stated that transmission period was June to December and the maximum was in August and September. Ganguli (1947) found both gut and gland infections during August and October.

CONTROL

Anti adult—The information so far available goes to show that *A philippinensis* is susceptible to insecticide sprays. The published report regarding the control of this species by residual insecticides are very meagre except for Nasiruddin (1952) who stated that in Gujrali in E Pakistan, *A philippinensis* disappeared entirely from the treated places and the treated walls remained lethal for nine months. The dosage he employed was 106 mgs per sq ft.

Anti larval—The naturalistic methods advocated by Iyengar (1944) for the control of breeding of *A philippinensis* are (1) covering the water surface with a dense growth of water hyacinth but it raises problem of its own. As complete cover is not possible this

TABLE I
Dissection results of *A. philippinensis*

| Observed | Area | Number dissected | Gut infection | Gland infection | Total infection | Per cent infection | Remarks |
|----------------------------------|------------------------------|------------------|---------------|-----------------|-----------------|--------------------|---|
| Feegrade, 1926 | Bhamo, Burma | 189 | 2 | 1 | 3 | 16 | |
| Sur, P., 1928 | Bengal | 223 | 3 | 5 | 7 | 31 | |
| Sur and Sur, 1929 | Krishnagar, Bengal | 770 | — | 15 | 15 | 20 | |
| Strickland, 1929 | Cachar, Assam | 2,410 | 0 | 0 | 0 | — | |
| Ramsay, 1930 | Cachar, Assam | 6,895 | 0 | 0 | 0 | 0 | |
| Sweet, 19293 0 | Mysore, South India | 17 | 0 | 0 | 0 | — | |
| Timbers, 1935 | Bengal | 12 594 | — | — | — | 14 | |
| Ramsay and Macdonald, 1936 | Assam | 12 466 | 0 | 0 | 0 | — | |
| Toumanoff 1936 | Tokin (1931-33) | 592 | 0 | 0 | 0 | — | |
| Niogi and Khan, 1937 | Bengal Dooars | 101 | — | — | 2 | — | |
| Iyengar, 1939 | Bengal | 1,918 | 81 | 76 | — | 72 | Sporozoite rate 40 Number with both gut and gland infection-139 |
| Iyengar 1940 | Bengal | 1,830 | 68 | 65 | — | 63 | Sporozoite rate 39 Number with both gut and gland infection-116 |
| Viewanathan <i>et al.</i> , 1941 | Assam (1931-1941) | 4,239 | 2 | — | 4 | — | |
| Sen, 1948 a and b | Madhagram, Calcutta (1916) | 180 | 0 | — | 12 | 66 | |
| Macan, 1948 | Kabaw and Kale Valley, Burma | 505 | 0 | 0 | — | — | |

often gives rise to intense culicine breeding, (2) complete removal of vegetation and (3) introduction of water into the area to raise the water table—wet cultivation to be encouraged. He also considered that drainage was not a suitable measure to control the breeding of *A. philippinensis* in Deltaic Bengal.

REFERENCES

- Bose K (1931) Mosquito survey of Barnagar. *Rec Mal Surv. Ind* 2 p 193-224
- Christophers S. R. (1912) Malaria in the Andamans. *Sci Mem Govt Ind* 56 Govt Press Calcutta
- Covell, G (1927) Report of an enquiry into malarial conditions in the Andamans. Govt Press, Delhi
- Feegeade E. H. (1926) Malaria of Bhamo Town. *D P H Burma* No 656 15 Mal 2
- Ganguli, N. (1947) Preliminary note on investigation of malaria in Bengal Orissa border South of Kharagpur. *Ind J Mal* 1 p 289-300
- Green, R. (1934) Annual report of the Institute of Medical Research for 1934. *FMS*
- Iyengar M. O. T. (1939) A year's work on dissection of *Anopheles* for natural malarial infection. *J Mal Inst Ind* 2 p 105-109
- Idem (1940) Further observations on vectors of malaria in Bengal. *Ibid*, 3 p. 115-123
- Idem (1942) Studies on malaria in the deltaic region of Bengal. *Ibid* 4 p 435-446
- Idem (1944) Problems relating to malaria control in Deltaic Bengal. *Ibid*, 5 ■ 435-448
- Krishnan S. V. (1940) Report of the Professor of Entomology and Rural Hygiene. *Report All India Inst Hyg Publ Hlth* 1939 ■ 32-36
- Macan T. T. (1948) Mosquitoes and malaria in the Kabaw and Kale Valleys Burma. *Bul Ent Res* 39, p 237-268
- Idem (1950) Malaria survey of the Arakan Region of Bengal and Burma, *Parasitology* 40 p 290-297

- McArthur, John (1950) The importance of Borneo Anopheles
A study of the relative importance of the different species of Borneo Anopheles from records of 24,000 dissections and other evidence by observers throughout North Borneo and Labuan Sarawak Brunei and Dutch Borneo 1914-49 *Ind J Mal*, 4, p 391-447
- Nasir ud Din (1952) A year's work of the national malaria committee teams in East Pakistan *Pakistan J of Hlth*, 1, p 21-41
- Nigot E K and Khan B M (1937) Winter malaria infections in Bengal *Doars Rec Mal Surv Ind*, 7, p 213-219
- Ramsay, G C (1930) Some findings and observations in an anopheline infectivity survey carried out in the Cachar District, Assam *Ind J Med Res*, 18 p 533-552
- Ramsay G, C and McDonald, D (1936) The species control of anophelines in India *Ind Med Gaz* 71, p 699-710
- Reid, J A and Wharton E H (1949) Annual report of the Division of Entomology Annual Report of the Institute of Medical Research Malaya for the year 1949 Govt Malaya, p 25-32.
- Idem* (1950) *Ibid*, Report 1950 p 14-20.
- Sen P (1935) Anopheles breeding in relation to rice cultivation in Lower Bengal *Rec Mal Surv Ind*, 5, p 97-103
- Idem* (1948a) Anopheles breeding in the rice fields of Lower Bengal Its relation with cultural practices and with the growth of rice plants *Ind J Mal*, 2, p 221-237
- Idem* (1948b) Natural infections of Anopheles in West Bengal *Ibid*, 2 p 239-245
- Strickland C. (1929) The relative malarial infectivity of some species of anopheline in Cachar (Assam) *Ind, J Med Res*, 17, p 174-182
- Sur P (1949) *A philippinensis* as a natural carrier of the malaria parasites in Bengal *Ind J. Med Res*, 16 p 45-47

- Sur, S N and Sur, P (1929) *Report of the Bengal Field Malaria Research Krishnagar Laboratory*, 1926-28 Calcutta
- Sweet, W C (1929-30) *Quarterly reports, Mysore Deptt Health*, Jan 1929 March 1930
- Timbers H G (1935) *Studies of malaria in W Bengal Rec Mal Surv Ind* 5, p. 345-370
- Toumanoff C (1936) *Anophelism in the Far East Coll Soc Path Exot Monog* 4, Masson and Cie, Paris
- Viswanathan, D K., Das, S and Gommen, A V (1941) *Malaria carrying anophelines in Assam J Mal Inst Ind*, 4, p. 297-306

III. *A STEPHENSI* LISTON, 1901

BY

K S KRISHNAN

(*Malaria Institute of India, Delhi*)

[October 2 1953]

THE possible existence of two races of *A stephensi* was thought of at various times (Knowles and Basu, 1934, Mulligan and Baily 1936 Ramsay and MacDonald, 1936) Sweet and Rao (1937) were able to show significant differences in the eggs (Appendix 1) and classified the species into two races—*A stephensi* type and *A stephensi* var *mysorensis*. They also showed that the two races differ in their adult habits. The varietal form is less hardy than type form more zoophilic and difficult to colonise. As few records are available where this species has been treated as two races, for purposes of this review both the races have been dealt with as one species but wherever it has been possible they have been discussed separately. Viswanathan (1950) regards type form as inhabitant of urban areas and the var *mysorensis* of the rural areas.

DISTRIBUTION

A stephensi is widely distributed in India (U P, Punjab, Delhi, Saurashtra Madhya Pradesh, Bombay, Hyderabad Madras Bengal, Bihar, Mysore Assam and Kashmir (vide map 2). Outside India, it is found in N W F P, Waziristan Sind Burma and China. Its distribution extends westwards through Bahrein Islands, Iran and Iraq to E Arabia. It has not been recorded from Ceylon, the Andamans, nor has it been found in Malaya.

BREEDING PLACES

A stephensi, in the urban areas, breeds in wells, cisterns, fountains, ornamental tanks artificial containers and in waters used for keeping the surface of cement concrete wet during building construction. In rural areas, it is found, breeding in pools, in stream beds and at the margin of stream itself, in seepages and marshy areas with a gentle flow of water, irrigation channels, reservoirs and springs, showing a preference to sunlit breeding places (Mulligan and Baily, loc cit). In Bahrein, the larvæ were found in

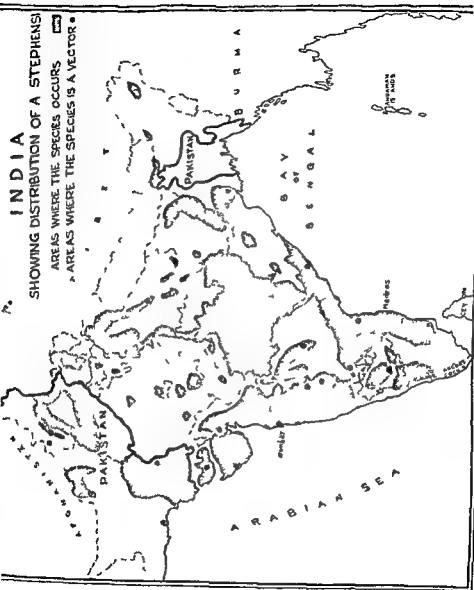
INDIA

SHOWING DISTRIBUTION OF A STEPHENSI

AREAS WHERE THE SPECIES OCCURS



AREAS WHERE THE SPECIES IS A VECTOR





drains shallow wells and garden pits containing seepage water. The upper limit of salinity in which larvæ were found was ≈ 750 parts per 10 000 (Afridi and Majid, 1938). In Bombay this species has been found breeding in water with high salinity sometimes reaching or even exceeding that of sea water (Bently 1911 Chalam 1926 Bana, 1943). In Iraq *A. stephensi* did not breed readily in localities which have high salinity or which are shaded by overhanging or emergent vegetation. Grassy depressions and pools yielded very high numbers of larvæ. They were rare in large expanse of water and abundant in small pools (Macan 1950). Roy (1931) in Calcutta found that this species could tolerate water with high degree of organic pollution and found breeding in drains contaminated with sewage. Russell and Mohan (1939) successfully reared *A. stephensi* larvæ in the laboratory in sullage water containing upto 50 parts per million of ammonia nitrogen. It breeds equally well in places exposed to direct sunlight and in dark places. Its larvæ have the power to sink deep and to remain there for long periods before reappearing at the surface.

ADULT HABITS

Resting places—There are conflicting views regarding the resting habits of *A. stephensi*. In Mesopotamia Christophers and Shortt (1921) found that this species is of retiring habit and its presence therefore, is not easily detected. Macan (*loc cit*) is also of the same view. In Calcutta, Knowles and Basu (1934) experienced difficulty in capturing adults in dwellings in spite of the species breeding in large number throughout the city. Ganguli (1935) also found this species very scarce in Calcutta. Strickland *et al* (1936) during one year's survey were able to collect 273 specimens of *A. stephensi* out of a total of 8 564 anophelines among the former only a few were noticed to have taken a blood meal. Senior White (1940) concluded that the day time resting place of the species is obscure in Calcutta. Mulligan and Baily (1936) in Quetta found that *A. stephensi* showed a marked preference for resting places in close proximity to human and animal dwellings. Out of 1 200 specimens of *A. stephensi* 1 119 were collected from human habitations or from situation in their immediate vicinity. In Quetta *stephensi* rested by day close to where it fed at night. It was rarely found in outdoor resting place. Afridi and Majid (*loc cit*) in Bahrain Islands came to the conclusion that *A. stephensi* selects its

day-time resting places in houses situated in the vicinity of its breeding grounds but that it makes daily incursions into the interior of the town in search of food. Subba Rao and Appa Rao (1945) in Vizagapatam found that this species was rare in pukka houses but plentiful in thatched huts and cattlesheds. Rao *et al* (1949) collected easily large numbers of adults from inside dwellings in the ceded districts of Madras. In a total collection of 3 885 *stephensi* adults 18 per cent were found in human dwellings, 32 per cent in cattle sheds and 50 per cent in mixed dwellings. Adults when resting indoors are usually found on palm leaves hanging vertically from the roof on men's kits especially leather belts, haversacks *etc* and under the projecting eaves of huts. It has also been observed in ceded districts of Madras that *A. stephensi* showed marked preference for vertical surfaces a common haunt being the junction of walls and ceiling. Attics used for storing fodder yielded a good number of this species (Rao *et al*, 1946).

Biting time—No experimental work has been done on the biting time of this species. It is presumed that it commences to bite at dusk or soon after. DeBurca and Jacob (1947) found *A. stephensi* feeding in the open at 0900 hours. They also observed that in early afternoon while sitting in rather a dark office it bit in numbers. Nursing *et al* (1934) in Mysore used a tent with human bait and made collections at 9 p.m. and midnight and again at 4 a.m. and 6 a.m. in the morning. In 9 p.m. and midnight catch *A. stephensi* formed 33 per cent of the catch and between 4 and 6 a.m. it was 67 per cent. The condition of the mosquitoes was not noted and hence it was difficult to assess the biting activity. In Baghdad, certain observations in 1941 showed that biting time of *A. stephensi* was over by midnight (Ramakrishnan, 1953).

Food preferences—Sweet and Rao (1937) stated that the type form feeds avidly on man. Roy *et al* (1938) found by precipitin test that 3.4 per cent had fed on man and 96.6 per cent on cattle in a total of 172 samples tested. Afridi *et al* (1939) found a 4 per cent of *A. stephensi* with human blood in a series of 360 positive precipitin test. Senior White (*loc cit*) stated that in Calcutta both the races are attracted to cattle rather than to man. Barber and Rice (1938) in Poona found no human positive in 43 positive precipitin tests. Rao *et al* (1946) found the anthropophilic index of *A. stephensi*

to be 0.8 per cent in a total positive precipitin reactions of 75.69 per cent had fed on cow

A series of precipitin tests of blood meals of *A. stephensi* were carried out in the laboratories of the Malaria Institute of India. In Bellary area the anthrophilic index was 11.3 per cent while 26 per cent were positive with bovine serum out of 118 tested. In Munirabad area (Hyderabad State) out of 24 blood meals tested 41 per cent gave positive reaction with human serum (October 1949—February 1950). The anthrophilic index in Ajmer area was as high as 47 per cent in a total of 201 blood smears tested (April 1950, Malaria Institute Report 1948-1950).

Flight range—Covell (1944) surmised that in urban areas this species has a flight range of $\frac{1}{2}$ mile. In rural areas it can fly a distance up to 3 miles Russell *et al* (1943). In Bahrain Islands Afridi and Majid (1938) found this species resting in huts $1\frac{1}{2}$ miles away from the nearest breeding place and thus assumed that distance to be the flight range.

Seasonal prevalence—The peak of *A. stephensi* breeding in Calcutta occurs in July and thereafter rapidly falls until December (Knowles and Basu 1939). In Quetta this species was more prevalent from July to September and then there was sudden fall towards the end of September and by early part of October adults of *A. stephensi* were extremely scarce (Mulligan and Bailly *loc cit*). In Iraq *A. stephensi* had two marked seasons in May and June and in October and November and in the intervening months it was scarce (Macan *loc cit*). In ceded districts of the Madras State Rao *et al* (1946) found that the peak months for this species were from November to March.

Hibernation—Mulligan and Bailly (*loc cit*) stated that in Quetta *A. stephensi* probably did not overwinter in the adult stage. Adults of *A. stephensi* showed a marked decline in numbers towards the cold months. In Iraq there was no evidence of hibernation and the species probably bred throughout the year and the numbers became reduced during the cold weather (Macan *loc cit*).

Swarming and mating—Swarming and mating of *A. stephensi* has not been observed in nature. Russell and Mohan (1939a) have described the swarming and pairing of the species inside a

colony cage and it would be of interest to read the original article Rao et al (1938) had no difficulty in colonising *A stephensi* type even in small cages but *A stephensi* var *mysorensis* resisted all attempts at colonisation and no generation beyond F_1 could be obtained Senior White (loc cit) observed that the fertility of var. *mysorensis* in captivity was very low But Russell and Mohan (1941) successfully colonised var *mysorensis* through nine generations

Longevity — Knowles and Basu (1943) carried out studies on the infectivity of *Anopheles stephensi* During these studies they kept mosquitoes alive under controlled conditions of temperature and humidity after giving one blood meal and later fed on fruit juice and water They came to the conclusion that the death rate increased at high temperature At 100°F , none survived long enough to become infective In their words "At temperatures between 50°F and 80°F a high degree of relative humidity does not seem to be essential for the longevity of *A stephensi* as long as sufficient food and water are provided, but at higher temperatures this factor becomes of great importance." The percentage of survivors of this species was found to be highest at low temperatures and with higher percentage of humidity

RELATION TO MALARIA

This is an important vector under rural conditions in Western and North Western India, the Persian Gulf and under urban conditions in certain localities (Bombay Bangalore and Lucknow).

A stephensi mysorensis was considered less important as a vector than the type form but Senior White (loc cit), and Subba Rao and Appa Rao (loc cit) have shown it to be the chief rural carrier in Vizagapatam Natural infections recorded in this species (both races) are given in Table I.

City of Bombay had a severe epidemic of malaria in 1901 It was due to *A stephensi* establishing itself to breeding in wells and cisterns throughout the city, an unusual adaptation which this species alone has shown (Christophers, 1949)

A stephensi has caused severe malaria epidemics in certain areas In the year 1929, Lucknow city had a major malaria epidemic which was quite peculiar in that it was during late spring (April—September) instead of in the autumn as usual in this part of

India *A stephensi* was solely responsible for causing this epidemic and the infections were predominantly of benign tertian. The mortality rate due to fever in the month of May was as high as 6.05 per 1 000 (Banerjee 1930).

In September 1941, when troop concentration commenced in and around Baghdad there was a sharp epidemic of malaria which affected the troops as well as the local urban and rural populations. The only mosquito found infected was *A stephensi*. The epidemic was quickly brought under control by space spraying with pyrethrum everyday for about four weeks (Ramakrishnan *loc cit*).

CONTROL

For the control of urban malaria transmitted by *A stephensi* Covell (1949) recommended the provision of a continuous high pressure supply of filtered water in order to do away with the necessity of storing water on premises and wells and cisterns to be made mosquito proof. This species is very susceptible to DDT. Effective control with this insecticide has been obtained by Afridi and Bhatia (1947), Viswanathan (1950) and Adhikari and Ganguli (1949). The dosage used ranged from 25 to 50 mg per sq ft.

A STEPHENSI AS A USEFUL LABORATORY INSECT

A stephensi is a good laboratory insect. It colonises easily in small cages; it adjusts itself to varying larval and adult environments and feeds equally well on man and other animals and is highly susceptible to experimental infections. Russell and Mohan (1939b) suggested that *A stephensi* may be used as a measuring rod to gauge the significance of experimental infections in other species in India.

A stephensi has also been found susceptible to experimental filarial infections of *mf bancrofti* and not of *mf malayi* (Rao and Iyengar, 1932 and Raghavan and Krishnan 1949). This insect therefore, may sometimes be conveniently used for xenodiagnosis in human filarial infections.

DISCUSSION

Roy *et al* (1938) expressed doubts regarding the classification of *A stephensi* into two biotypes. They agree that variations in size of oöcyte exist, but they do not agree with the view that the type form carries and the other does not carry malaria. This point they

have discussed in the light of the precipitin tests conducted by them in Calcutta. To quote them 'The fact that only three out of a hundred specimens of *stephensi* which were subjected to precipitin test were found to have fed on man is a matter that needs serious consideration and indicates that the natural inclination of this species is to divert its attention to animals in the stable rather than to human habitations. The findings of Senior White (*loc cit*) and Subba Rao and Appa Rao (*loc cit*) also go to show that the varietal form is an efficient vector. As regards the behaviour of these two races in captivity Russell and Mohan (1941) have shown that they could colonise *A. stephensi* var *mysorensis* adopting special technique. Sweet *et al* (1938) tried cross breeding of these two races and reported that 'there would seem to be quite a definite natural barrier to successful cross breeding between types B and M, since with crosses in both directions only a small minority of the females laid eggs and a still smaller minority laid viable eggs. From the viable eggs of the very few cross mated females laying it was possible to raise successive generations of hybrids but in each generation there were instances of the laying of sterile eggs.' It would be necessary to have more information on this point to interpret the cross breeding of the two races.

From the above remarks it seems necessary that these two races have to be studied in more detail and it is imperative wherever possible to mention the particular race of *stephensi* one is encountering. Without this the knowledge of distribution of these two races is very imperfect. Covell (1944) mentions that var *mysorensis* has been reported to occur in Poona and Mysore State (not Mysore City or Bangalore), Vizagapatam and he believes that it might have a wider distribution. It is not known if var *mysorensis* occurs outside India.

REFERENCES

- | | |
|---|---|
| Abraham, A C | (1932) <i>Rec Mal Surv Ind</i> 3, p 149 |
| Adhikari, A K and Ganguli N | (1949) <i>Ind J Mal</i> 3 p 1 |
| Afridi, M K and Bhatia M L | (1947) <i>Ibid</i> , 1, p 279 |
| Afridi, M K and Majid, A | (1938) <i>J Mal Inst Ind</i> 1 p 427 |
| Afridi, M K, Jaswant Singh and Harwant Singh | (1939) <i>Ibid</i> 2, p 219 |
| Afridi, M K, Majid, A and Jaswant Singh | (1938) <i>Ind J Mal</i> , 1, p 187 |

- Bana F D (1943) *J Mal Inst Ind*, 5 p 123
- Banerjee A C (1930) *Ind Med Gaz* 65 p 149
- Barber M A and Rice J B (1938) *J Mal Inst Ind*, 1 p 37
- Bentley, C A (1921) Report on Malaria in Bombay—Govt Press, Bombay
- Chalam B S (1926) *Ind Med Gaz*, 61 p 375
- Idem* (1927) Quoted by Covell—*Ind Med Res Mem.* 7 p 79
- Christophers S R. (1949) *Malariaology* p 698 W B Saunders Company Philadelphia and London
- Christophers, S R and Shortt H E. (1921) *Ind J Med Res*, 8 p 508
- Covell G (1928) Malaria in Bombay Govt. Press, Bombay
- Idem* (1944) *J Mal Inst Ind* 5 p 309
- Idem* (1949) *Malariaology* p 1439 W B Saunders Company, Philadelphia and London
- Covell G and Bailey J B (1934) *Rec Mal Surv Ind* 4 p. 249
- DeBurea B and Jacob, V P (1947) *Ind J Mal* 1 p 413
- Ganguli A C (1935) *Rec Mal Surv Ind*, 5, p. 213
- Godbole, S H Ramachandra (1949) *Ind J Mal* 2, p 213
- Rao T and Viswanathan D K.
- Hodgson E C (1914) *Ind J Med Res*, 11 p 405
- Jaswant Singh and Jacob V P (1943) *J Mal Inst Ind* 5 p 127
- King H H and Iyer, M K R (1929) *Supp Ann Rep King Inst., G. Ind* 1927 28 p 15
- Knowles R and Basu B C (1934) *Rec Mal Surv Ind* 5, p. 291
- Idem* (1943) *J Mal Inst Ind* 5 p. 1
- Liston W C. (1908) *J Bomb Nat Hist Soc* 18 p 872
- Macan T T (1950) *Lond Sch Hyg Trop. Med Mem* 7, p 113
- Mayne B (1928) *Ind J Med Res* 18 p 1073
- Mulligan, H W and Bailey J D (1936) *Rec Mal Surv Ind*, 6 p 289
- Nursing D Rao B A and Sweet W C (1934) *ibid* 4 p 243
- Raghavan N G S and Krishnan K S (1949) *Ind J Mal* 3 p 249
- Ramsay G L. and MacDonald G (1930) *Ind Med Gaz* 71 p. 699
- Ramakrishnan S P (1953) *Personal communication*
- Rao Bhaskar R Rao (1946) *J Mal Inst Ind* 6, p 323
- II Ramanatha and Sundaresan, B.
- Rao B A Sweet, W C. and Subba Rao A M (1938) *Ibid* 1 p 261
- Rao S S and Iyengar M O T (1932) *Ind J Med Res* 20 p 25
- Report of the Malaria Institute of India (1951) Manager of Publications Govt. of India Delhi

- Roy, D N (1931) *Ind J Med Res* 19, p 617
- Roy, D N, Chandra, S N and Eddons, L B (1938) *J Mal Inst Ind*, 1 p 417
- Russell, P F and Moban, B N (1939a) *Ibid*, 2 p 433
- Idem* (1939b) *Ibid*, p 425
- Idem* (1941) *Ind Med Gaz*, 76, p 219
- Russell P F, Rozeboom L E & Stone A (1943) *Key to Anopheline mosquitoes of the World*
American Entomological Society Academy of Natural Sciences Philadelphia
- Senior White, R (1940) *J Mal Inst Ind* 3 p 349
- Senior White, R and Venkat Rao V (1943) *Ibid*, 5 p 187
- Sddons L B (1946) *Ibid* 6 p 367
- Sinton, J A (1917) *Ind, J Med Res* 5 p 195
- Strickland C Roy D N and Chaudhuri H P (1933) *Ibid*, 20 p 819
- Idem* (1936) *Riv Mos* 15 Sez 1 p 172
- Subba Rao D and Appa Rao, M (1945) *J Mal Inst Ind* 6 p 95
- Sweet W C and Rao, B A (1931) *Rec Mal Surv Ind*, 2, p 655
- Idem* (1937) *Ind Med Gaz*, 72 p 665
- Sweet W C Rao B A and Subba Rao A M (1938) *J Mal Inst Ind*, 1 p 149
- Viswanathan D K (1950) *Malaria and its control in Bombay State*
Chutrasala Press 1026 Sadash v
Poona 2

TABLE I
Infections recorded in A. Stephensi

| Observer | Locality | Number dissected | No. of gutta infected | Oocyst rate per cent | Number of eggs and oocysts infected | Sporozoite rate, per cent | Remarks |
|----------------------|--------------|------------------|-----------------------|----------------------|-------------------------------------|---------------------------|-------------------------|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Liston (1908) | Bombay | | | | | | Per cent infect on 25 0 |
| Bentley (1911) | Bombay | 1 228 | 91 | 7.4 | 30 | 2.4 | |
| Total 1909-1912 | Bombay | 1 227 | | | | | |
| Hodgson (1914) | Delhi | 210 | 2 | 1.8 | 1 | 2.2 | |
| Clinton (1917) | Kohat | 45 | | | | | |
| Mayne (1928) | Saharanpur | 248 | 0 | | 5 | 6.7 | |
| Banerjee (1930) | Lucknow | 75 | 7 | 9.3 | 5 | 3.3 | Per cent infection 4 6 |
| Chalam (1927) | Bombay | 151 | 8 | 1.3 | 33 | 1.8 | |
| Covell (1928) | Bombay | 671 | 17 | 2.5 | 1 | 0.6 | |
| King and Iyer (1929) | Mopad Madras | 166 | 9 | 5.4 | | | |
| Sweet and Rao (1931) | Mysore State | 2 710 | 2 | 0.07 | | | Per cent infection 3 5 |
| Abraham (1932) | Hyderabad | 153 | | | | | |

APPENDIX I

Mean egg measurements of two forms of *A. Stephensi*

SWZET, RAO AND SUBBA RAO (1938)

| | Length (Microns) | | Breadth including floats (Microns) | | Length of float (Microns) | | Number of ridges on one side of float | | Proportion of length covered by the floats | |
|--|------------------|--------------------|------------------------------------|--------------------|---------------------------|--------------------|---------------------------------------|--------------------|--|--------------------|
| | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation | Mean | Standard deviation |
| <i>A. stephensi</i> | 555 ±0.30 | 24 ±0.30 | 204 ±0.15 | 12 ±0.11 | 294 ±0.20 | 23 ±0.20 | 18 ±0.20 | 1.6 ±0.01 | 0.53 ±0.0004 | 0.03 ±0.0003 |
| <i>A. stephensi</i> var <i>myiorenensis</i> | 476 ±0.20 | 24 ±0.14 | 106 ±0.10 | 12 ±0.07 | 218 ±0.17 | 20 ±0.12 | 13 ±0.01 | 1.2 ±0.07 | 0.46 ±0.0003 | 0.03 ±0.0002 |

IV. *A. SUNDAICUS* RODENWALDT, 1926

BY

V VENKAT RAO

[December 7 1955]

A. Sundaicus is the only member of the *ludlowi* group of anophelines which has been recorded in or near India. Till King (1932) classified the various members of this group as distinct species identifiable by morphological differences among the adults. *A. sundaicus* was referred to as *A. ludlowi* by Indian workers. It may be emphasised that the latter species has a very limited distribution and does not occur in India. It is recorded with certainty only in the Philippine Islands and possibly also in Formosa.

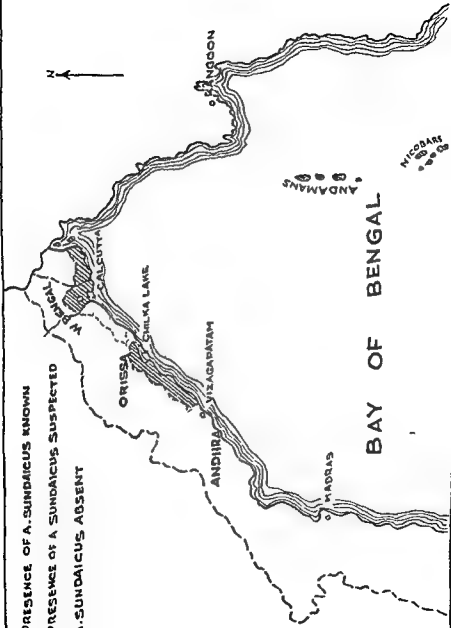
DISTRIBUTION

In India *A. sundaicus* has been found only in the coastal areas of West Bengal, Orissa and North Vizagapatam District. Even in these areas, the distribution is somewhat patchy and not always continuous. While, in West Bengal, there is a fairly uniform distribution up to about twenty miles southwest of Calcutta, there is yet no evidence of the presence of this species further south or in the 200 miles length of the sea coast between Puri and the Bengal border in Orissa itself. The southernmost limit of *sundaicus* prevalence is the Vamsadhara River in the North Vizagapatam District. Besides these areas, *A. sundaicus* is also recorded in the Andaman and Nicobar Islands in the Bay of Bengal (Map 3).

Outside India, the distribution is much wider and embraces practically the whole of the oriental region viz. East Pakistan, Burma, Thailand, Indo China, South China, Malaya, Great and Little Sunda Island and as far east as Rcma (Covell 1944).

BREEDING PLACES

A. sundaicus is well known for its close association with coastal conditions and its preference for breeding in brackish waters. The species breeds pre-eminently in salt swamps, in collections of brackish water behind coastal bunds and such like situations (Christophers, 1933), but not in waters subject to the influence of daily tides or in virgin mangrove (Covell, loc. cit.). In the Calcutta area, larvae of



PRESENCE OF A. SUNDAICUS KNOWN

PRESENCE OF A. SUNDAICUS SUSPECTED

A. SUNDAICUS ABSENT

BAY OF BENGAL

RANGOON

NICOBARS

ANDAMANS

MADRAS

VIZAGAPATAM

ORISSA

CHILKA LAKE

CALCUTTA

BENGAL

N

sundaicus are found mostly in standing waters like lakes, tanks and ponds and in large railway borrowpits. In Orissa, the main breeding place of *sundaicus* is the Chilka Lake, which is over 500 sq miles in extent. In addition, considerable numbers of larvæ are found in tanks, ponds and railway borrowpits containing fresh or saline water, and occasional breeding may also be found near the mouths of rivers and in ricefields situated along the margin of the Chilka Lake. The breeding places in the North Vizagapatam District are almost exclusively tanks, ponds and borrowpits containing fresh water.

Outside India, except in Sumatra,¹ *A. sundaicus* is everywhere a brackish water breeder. There was a fresh water form of *sundaicus*—a potent vector—in Sumatra breeding in fresh water fish ponds but it was eliminated when the breeding places were eradicated (Bonne Wepster and Swellengrebel, 1953). Covell (*loc cit*) refers to the presence of fresh-water *sundaicus* in the narrow valleys among the mountains running parallel to the west coast of Sumatra, at a height of 1,500 to 3,250 feet above the sea level.

The brackish water form, which is more commonly met with, breeds extensively in moderately saline waters. In Orissa, Covell and Singh (1942) found the optimum salinity of its breeding places to be from 600 to 800 parts per 100,000. Senior White and Adhikari (1939), working earlier in the same area, concluded that the optimum salinity was 869 parts per 130,000, while the inhibitory salt value was 2,300 parts. They, however, found scanty breeding in waters with salinity higher than 1,300 parts. On the other hand, Christophers (1912) found the optimum salinity in the Andamans to be 400 parts and Iyengar (1931) in Bengal 150 to 250 parts per 100,000.²

Working in Puri Town Panigrahi (1942) observed larvæ in waters with salinities lower than 100 parts; in fact, he did not find



sundaicus breeding in brackish waters at all, though such waters exist there in good numbers. Pursuing their studies in the Chilka Lake area, Senior White *et al* (1947) found larvæ at practically all salinity values below 2,300 but came to the conclusion that, in that area, larvæ were more likely to be found in fresh than in saline waters but the output from the latter, particularly from those with values between 700 and 800, was much higher.

The breeding places in the North Vizagapatam District, as already stated, are mostly fresh waters, with salinities well below 100 parts per 100,000.

Many Indian workers have also observed the close association of *sundaicus* larvæ with certain types of aquatic vegetation. Senior White and Adhikari (*loc cit*) observed that the favourite breeding place of *sundaicus* in the Chilka area was among the putrefying masses of sub aqueous plants, *Potamogeton pectinatus* and *Halophila otata*, which are uprooted by wave-action and become bound together into plaques by the alga, *Lyngbya aestuarii*. In the vicinity of Calcutta, the association with *Oscillatoria germine*, *Lyngbya confertoides*, and *Oedogonium spp* was very marked. Covell and Singh (*loc cit*) found *sundaicus* larvæ in the Chilka area in association with thirteen types of plants and eight types of algæ, *Najas*, *Ceratophyllum* and *Hydrilla* among the plants and *Lyngbya*, *Anabena* and *Spirogyra* among algæ being the most important. In fresh waters too, association with the same three plants and *Spirogyra* was observed (Venkat Rao and Ramakrishna, 1947).

Iyengar (*loc cit*) has stated that besides salinity, organic pollution of the breeding place is a cardinal condition of *sundaicus* breeding. This is in accordance with the observation of Rodenwaldt and Essed (1925) in the East Indies that this species breeds readily in waters polluted with sewage. Covell and Singh (*loc cit*) have recorded that the principal factor affecting the breeding of *sundaicus* is undoubtedly the presence or absence of putrefying masses of algæ and other weeds and that salinity probably operates only in so far as it affects the growth of the weeds. All this suggests that water polluted by rotting organic matter favours the breeding. On the other hand, Venkat Rao and Ramakrishna (*loc cit*) have shown that in fresh waters, the breeding occurs when the plants are still growing and when, therefore, no putrefaction occurs.

In fact, when the plants are removed in the course of malaria control measures, the water becomes turbid and polluted and the green alga, *Microcystis aeruginosa* grows in quantities and the breeding of *sundanicus* disappears.

ADULT HABITS

Resting places—Christophers (1933) says that adults of *sundanicus* are found abundantly in houses and cowsheds. Covell and Singh (*loc cit*) collected altogether 16,398 specimens, of which 8,835 came from huts occupied only by human beings, 4,237 from mixed habitations and 3,866 from cowsheds. Thus, *sundanicus* is shown to rest in both human and animal habitations but predominantly in the former.

However, Senior White (quoted by Covell and Singh, *loc cit*) observed that, in the same area, the numbers found in houses and cowsheds during cool weather are about equal but that, when it becomes warmer, the species does not appear to prefer cowsheds to the same extent.

It must, however, be remembered that the density of *sundanicus* population varies to a very great extent from year to year. Even in the Chilka area, where it has been in existence for about fifty years, its prevalence in any particular year is uncertain. Fry (1911) and Sarathy (1932) investigated the area and encountered hyperendemic conditions without *sundanicus* having been located. The latter author suspected its presence there and specially looked for it but could not find a single specimen. During the first year of the investigation by Covell and Singh (*loc cit*), they were able to collect only 150 specimens for dissection, against 4,718 in the second year and 3,158 in the third year. During the early part of 1942, Venkat Rao *et al* (1942) found the exceedingly heavy density of over a hundred per man-hour in houses. The resting habits of *sundanicus* are, therefore, inapplicable for generalisation. When the species is present in small or moderate numbers, it is likely to rest in houses or cowsheds according to its natural preference. But, when it prevails in very large numbers—as it does in certain years—it has to overflow into other man-made structures or resort to outdoor shelters. In such cases, the preferred resting places are difficult to ascertain.

Feeding time—The writer's experience indicates that, in normal years, feeding takes place more during the first half of the night.

sundaicus breeding in brackish waters at all, though such waters exist there in good numbers. Pursuing their studies in the Chilka Lake area Senior White *et al* (1947) found larvæ at practically all salinity values below 2,300 but came to the conclusion that, in that area, larvæ were more likely to be found in fresh than in saline waters but the output from the latter, particularly from those with values between 700 and 800, was much higher.

The breeding places in the North Vizagapatam District, as already stated, are mostly fresh waters, with salinities well below 100 parts per 100,000.

Many Indian workers have also observed the close association of *sundaicus* larvæ with certain types of aquatic vegetation. Senior White and Adhikari (*loc cit*) observed that the favourite breeding place of *sundaicus* in the Chilka area was among the putrefying masses of sub aqueous plants, *Potamogeton pectinatus* and *Halophila ovata* which are uprooted by wave action and become bound together into plaques by the alga, *Lyngbya aestuarii*. In the vicinity of Calcutta, the association with *Oscillataria germinata*, *Lyngbya confervoides*, and *Oedogonium spp* was very marked. Covell and Singh (*loc cit*) found *sundaicus* larvæ in the Chilka area in association with thirteen types of plants and eight types of algæ, *Najas Ceratophyllum* and *Hedvillia* among the plants and *Lyngbya Anabena* and *Spirogyra* among algæ being the most important. In fresh waters too association with the same three plants and *Spirogyra* was observed (Venkat Rao and Ramakrishna 1947).

Iyengar (*loc cit*) has stated that besides salinity, organic pollution of the breeding place is a cardinal condition of *sundaicus* breeding. This is in accordance with the observation of Rodenwaldt and Essed (1925) in the East Indies that this species breeds readily in waters polluted with sewage. Covell and Singh (*loc cit*) have recorded that the principal factor affecting the breeding of *sundaicus* is undoubtedly the presence or absence of putrefying masses of algæ and other weeds and that salinity probably operates only in so far as it affects the growth of the weeds. All this suggests that water polluted by rotting organic matter favours the breeding. On the other hand, Venkat Rao and Ramakrishna (*loc cit*) have shown that in fresh waters, the breeding occurs when the plants are still growing and when therefore, no putrefaction occurs.

In fact, when the plants are removed in the course of malaria control measures, the water becomes turbid and polluted and the green alga, *Microcystis aeruginosa* grows in quantities and the breeding of *sundaeus* disappears.

ADULT HABITS

Resting places—Christophers (1933) says that adults of *sundaeus* are found abundantly in houses and cowsheds. Covell and Singh (*loc cit*) collected altogether 16,398 specimens, of which 8,835 came from huts occupied only by human beings, 4,237 from mixed habitations and 3,866 from cowsheds. Thus *sundaeus* is shown to rest in both human and animal habitations but predominantly in the former.

However, Senior White (quoted by Covell and Singh, *loc cit*) observed that, in the same area, the numbers found in houses and cowsheds during cool weather are about equal but that, when it becomes warmer, the species does not appear to prefer cowsheds to the same extent.

It must however, be remembered that the density of *sundaeus* population varies to a very great extent from year to year. Even in the Chilka area, where it has been in existence for about fifty years, its prevalence in any particular year is uncertain. Fry (1911) and Sarathy (1932) investigated the area and encountered hyperendemic conditions without *sundaeus* having been located. The latter author suspected its presence there and specially looked for it but could not find a single specimen. During the first year of the investigation by Covell and Singh (*loc cit*), they were able to collect only 150 specimens for dissection, against 4,718 in the second year and 3,158 in the third year. During the early part of 1942, Venkat Rao et al (1942) found the exceedingly heavy density of over a hundred per man-hour in houses. The resting habits of *sundaeus* are, therefore, inapplicable for generalisation. When the species is present in small or moderate numbers, it is likely to rest in houses or cowsheds according to its natural preference. But, when it prevails in very large numbers as it does in certain years, it has to overflow into other man-made structures or resort to outdoor shelters. In such cases, the preferred resting places are difficult to ascertain.

Feeding time—The writer's experience indicates that, in normal years, feeding takes place more during the first half of the night.

than in the second³ When the species prevails in very large numbers, feeding may take place throughout the night and, those specimens which cannot get the opportunity to feed during the night, may feed in the early morning hours on persons seated in the darker parts of rooms

Food preferences—Covell and Singh (*loc cit*) have stated that 77 per cent of their total collection of 16,938 specimens was from rooms in which human beings spent the nights and that this fact was suggestive, indicating that *sundaicus* has a strong predilection for human blood⁴

Senior White (1947) obtained results of precipitin tests on 90 specimens, all from houses, which revealed the anthropophilic index of only 5.6 per cent Majority of these specimens were collected from a village at a time when the infection rates were high and were more conformable to endemic than to epidemic conditions If this small number is taken to be a representative sample, it only illustrates how a quite appreciable infection rate can exist in the face of a very low anthropophilic index

Gonotrophic cycle—There is no record of observations on this point

Swarming and mating—Two observations on the swarming and mating behaviour of this species were made in the Chilka areas by Venkat Rao *et al* (*loc cit*) both in January 1942 between 5 and 6 p.m. (Indian Standard Time) On the first occasion, there was a very large mixed swarm of both *A. sundaus* and *A. subpictus* The swarm, consisting of an estimated number of at least 5,000, took place at a height of 6 feet over the elevated railway station platform The mosquitoes made dancing movements, both up and down and circular On the second occasion, instead of one large swarm at one place, there were several groups each consisting of only a few hundred specimens, scattered over half the length of the platform

3 Swellengrebel and S de Graaf (1919) have recorded that the species is voracious feeder and bites by day as well as by night.—Editor

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to feed on man in
with human blood
present in normal
anthropophilic index

On both the occasions mating was observed. A number of copulating pairs were seen and, in almost every case, such pairs came out of the group and were separated outside the swarm after a transient period. Two copulating pairs were collected into a sucking tube; one was *sundanicus* and the other *subpictus*. All mosquitoes collected from the swarms were fresh unrubbed and fed specimens.

The main breeding place of *sundanicus* at the time was the Chilka Lake about two miles away from the railway station. As there was no evidence of swarming at any point between the railway station and the Chilka Lake, it appeared that the tendency of these mosquitoes to swarm at that particular spot was due to the radiation of heat from the raised stone platform and from the nearby range of low hills. That *A. annularis* does not require such conditions for swarming has been shown by a subsequent observation, swarming having been seen not on raised ground, but at lower elevations not far away from the lake itself (Venkat Rao, 1954).

Flight range—A *sundanicus* is a powerful flier⁵ capable of traversing about two miles in search of food (Venkat Rao *et al*, *loc cit*). However, in exceptional circumstances when the density of the species is pushed up enormously, the dispersal may become much wider. Covell and Singh (*loc cit*) collected adult specimens in villages up to about six miles from the lake shore, including one recently hatched specimen. The range of infiltration stopped short of three miles where there was a belt of thick forest acting as a barrier. There was no local breeding to account for the adults found in these villages.

Hibernation—There is no information on this point⁶.

Longevity—No direct evidence on this point is available. Here again, longevity depends largely on the population density and, where the density varies very greatly from year to year, the longevity must also be affected and can at best be expressed in

5. Flight range of over one mile has been recorded by Covell (1924) and Porter (1924). Van Doremalen (1919) believed that the species could fly as far as 5 km.—Editor

6. But the species being confined to the coastal areas with moderately warm climate all the year round there is no likelihood of the phenomenon occurring in its life cycle.—Editor

terms of 'strong and lean' years. In Indo-China Treillard (1934) observed under laboratory conditions the species lived longer than either *minimus* or *candidiensis*.

RELATION TO MALARIA

In the Calcutta area Iyengar (*loc cit*) found infection rates between two and six per cent. Senior White and Adhikari (*loc cit*) dissected 659 specimens in the Chilka area and found a total infection rate of 2.3 per cent and a sporozoite rate of 0.7 per cent. Covell and Singh (*loc cit*) dissected 9,307 specimens and found a total infection rate of 0.9 per cent and a sporozoite rate of 0.5 per cent. Working with purely fresh water specimens Panigrahi (*loc cit*) dissected in Puri Town 617 specimens and found a total infection rate of 1.9 per cent and a sporozoite rate of 1.1 per cent. In the fresh water areas of North Vizagapatam District Senior White *et al* (*loc cit*) dissected altogether 1,280 specimens and found a total infection rate of 4.7 per cent and a sporozoite rate of 2.6 per cent.⁷

As the infection rates in the Chilka area and the adjoining North Vizagapatam area showed significant differences, the hypothesis was held out that in these areas the salt water form was practically harmless and the fresh water form was a potent vector. In order to test the validity of this hypothesis the fresh water breeding in one particular locality of the Chilka area was completely eliminated without affecting the salt water breeding. Then 495 specimens, all obviously saline water breeders, were dissected and only one gut infection was encountered giving a total infection rate of 0.2 per cent and a sporozoite rate of nil (Senior White *et al*, *loc cit*).

It thus appears that whatever the status of *sundaicus* in West Bengal may be, the saline water form in Chilka area and further south is a poor vector and the fresh water form there is much more dangerous.

There is another disturbing possibility where *sundaicus* is concerned. Unlike many other anopheline species *sundaicus* is capable of invading and colonising new territories. A fresh invasion

⁷ Tyssul Jones (1950) has put forward indirect evidence to show that it is a vector in Kyaukpadaung Bamar Islands, Burma.—*Editor*

results invariably in violent epidemic outbreaks and, if the species can establish itself in the new area on a more permanent basis, endemic conditions will soon prevail. In fact, many areas in India where *sundaicus* is now prevalent have been invaded in this manner in comparatively recent times.

VARIETIES OR RACES IN *SUNDAICUS*

On account of the apparent differences in the behaviour and vectorial capacity of *sundaicus* in Orissa and North Vizagapatam areas, it was thought that the species might really be a complex of two races or forms, one breeding in saline and the other breeding in fresh waters. Further work suggests that the two forms can be distinguished by the difference in the number and shape of the leaflets of their phallosomes (Venkat Rao and Ramakrishna 1950) somewhat similar to those in the corresponding forms of Sumatra found by Bonne Wepster and Swellengrebel (*loc cit*). Among the salt water forms, there appear to be at least two races or varieties in Singapore, according to Taylor (1943).

CONTROL

Anti-larval measure—To attempt to control the breeding of *sundaicus* through chemical larvicides like paris green on a large scale is a costly proposition. Naturalistic measures described by Venkat Rao and Ramakrishna (1947) and Venkat Rao (1950) such as deweeding etc might be cheaper and more efficient. However, while these measures are appropriate for limited localities, their extension to large areas would involve such an amount of expert organization and supervision which cannot always be afforded.

In Malaya, Nair (1949) used 5 percent DDT kerosene oil solution as a barrier spray at the rate of one ounce of DDT per 1000 sq ft. He found one round of application effective for 9-14 days. Same formulations sprayed at the rate of 200 mg DDT per sq ft as indoor residual spray by Van Tiel and *sundaicus* for a period of six months. kerosene oil at the rate of one quart per reported satisfactory results in the Chikla and Coastal area around Vizagapatam lasted for 6-8 weeks.

There is now evidence resistance to DDT in two Indonesian localities. These localities are area of Tanjung Priok and approximately 200 kilometers east the Jakarta coastal area. It is resistant to DDT as shown out at Calcutta by the Malayan rat on of DDT for *sundaicus* anopheline species in India. Editor

Anti-adult measures—It may be possible to control *sundaicus* by indoor residual spraying. This method has actually been in force in the Chulka area for the last two years but the results are not yet available and, even if the method may prove to be successful, one has still to be careful when dealing with an elusive mosquito like *sundaicus* specially in view of the disquieting results observed by Crandell (1954) in the Djakarta area of Indonesia.

In India *sundaicus* is capable of being eradicated owing primarily to the fact that it is occupying an extremely narrow marginal zone in the area of its distribution and is thus susceptible for eradication measures (Venkat Rao, 1955).

REFERENCES

- | | |
|---|--|
| Bonne Wepster, M and Swellengrebel, N H | (1953) <i>The Anopheline Mosquitoes of the Indo-Australian Region</i> p 400 J H de Bussy, Amsterdam |
| Chang T L, Watson, R B and Chow, C Y | (1950) <i>Ind J Mal</i> 4, p 281 |
| Chetophers, S M | (1912) <i>Sci Mem Ind Govt</i> , 56 Govt Press Calcutta |
| <i>Idem</i> | (1933) <i>Fauna of British India</i> , Vol 4 p 24, Taylor and Francis London |
| Covell G | (1927) <i>Report of an inquiry into malarial conditions in the Andamans</i> Govt Press Delhi |
| <i>Idem</i> | (1944) <i>J Mal Int Ind</i> , 5 p 399 |
| Covell, G and Singh, P | (1952) <i>Ibid</i> , 4, p 457 |
| Crandell H A | (1954) <i>Mosquito News</i> 14, p 194 |
| Fry, A B | (1911) <i>First Report on Malaria in Bengal</i> Bengal Sectt Book Depot, Calcutta |
| Iyengar M O T | (1931) <i>Ind J Med Res</i> , 19 p. 504 |
| King, W V | (1932) <i>Phil J Sci</i> 47, p 305 |
| Neogi S K | (1936) <i>Rec Mal Sur Ind</i> 6, p 31 |
| Overbeek J M and Stoker, W J | (1937) <i>Malaria in the Netherlands Indies and its control</i> Kolff and Co. Batavia (Indonesia) |
| Panigrahi R G | (1942) <i>J Mal Inst Ind</i> , 4, p 423 |
| Porter, F H Ter | (1924) <i>Repts Dutch E Indian Medical Civil Service</i> 1924 1, p 99 |
| Rodenwaldt E and Essed W R F | (1925) <i>Med Volk Ned Ind</i> , 2, p 89 |
| Sarathy M K P | (1932) <i>Ind Med Gaz</i> , 67, p 254 |
| Senior White, R | (1947) <i>Ind J Mal</i> 1, p 3 |
| <i>Idem</i> | (1948) <i>Ibid</i> , 2, p 13 |

- Sen or White III and (1939) *J Mal Inst Ind* 2, p. 39,
Adhikari A. K.
- Sen or White III (1947) *Ind J Mal* 1, p. 81
Ramakrishna V. and Venkat
Rao V.
- Seelengruber N. H. and (1919) *Med. Burg. Ned. Ind* 6, p. 1
S. de Graaf J. M. H.
- Taylor F. H. (1943) Service Publication No. 5, p. 73. School
of Public Health and Hygiene
Sydney.
- Treillard M. (1941) *Bull. Soc. Path. Exot.* 27, p. 554.
- Tyssen Jones T. W. (1950) *Ind J Mal* 4, p. 239.
- Van Breeën (1919) Reported by Couell 1944.
- Venkat Rao V. (1950) *Ind J Mal* 4, p. 1.
- Idem (1954) *Bull. Nat. Soc. Ind. Mal. Mosq. Dis.* 2,
p. 191.
- Idem (1955) *Ind J Mal* 9, p. 353.
- Venkat Rao V. and (1947) *Ibid.* 1, p. 51.
Ramakrishna V.
- Idem (1950) *Ibid.* 4, p. 235.
- Venkat Rao V. Roy B. D. and (1942) *J Mal Inst Ind* 4, p. 405.
Jagannatha Rao P.
- Walch E. W. (1932) *Genet. T. J. Ned. Ind* 72, p. 68.

V A FLUVIATILIS JAMES, 1902

By

M I D SHARMA

(Malaria Institute of India, Delhi)

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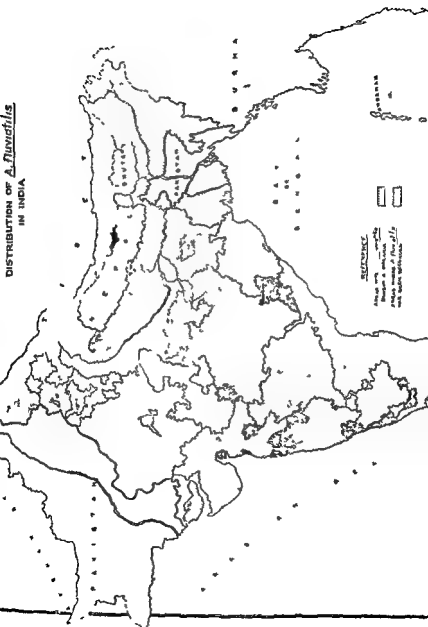
ANOPHELES FLUVIATILIS is a vector of considerable importance in India not only in hill and foothill regions but also in the vast irrigated tracts of the Deccan plateau. It has been incriminated as a vector in parts of East Central India, Peninsular India and Western Uttar Pradesh Terai. A *fluviatilis* is not commonly found below 1,000 ft. or at altitudes over 5,000 ft. above sea level.

DISTRIBUTION

It has a very wide distribution in the Indian sub continent (Map 4) and has been recorded from Bengal, Assam, Orissa, Bihar, Uttar Pradesh, Punjab, Madhya Pradesh, Bombay, Madras, Hyderabad, Mysore, Vindhya Pradesh, Madhya Bharat, Rajasthan, Kutch, Ajmer-Merwara, Jammu and Kashmir and Delhi (Covell 1927, 1931a, 1931b, Puri, 1936, 1948). Outside India it is found in Ceylon, Burma, Thailand, Indo-China (Russell *et al.*, 1943), Hong-kong (Burke 1937), Turkistan, Iraq and Bahrein Islands, Persian Gulf (Covell, 1944).

BREEDING HABITS

According to Covell and Harbhagwan (1939) *A. fluviatilis* is a clear water breeder, normally found in irrigation channels and streams with grassy edges and a moderate current resorting to shallow wells during the monsoons when the usual breeding places are washed out by heavy rains. They along with a number of other workers found that in the Western Ghats ricefields did not offer ideal breeding places for this species. Vedamanickam (1952) confirmed these observations and found that in the Wynad (a hilly taluk of Malabar District in Madras State) breeding places like streams, ricefields drainage channels and contour drains with flowing water accounted for 88.9 per cent of the total number of larvae of *A. fluviatilis* collected, while the remaining 11.1 per cent were found in stagnant water collections in wells, ricefields, marshes and pools in the river bed. Ramachandra Rao

DISTRIBUTION OF *A. fluviatilis*
IN INDIA

(1945), while confirming the observations of previous workers that streams and channels are the preferred habitats of the species determined that in Bombay State ricefields, both fallow and growing constitute important sources of the species

In the Wynad, *A. fluviatilis* was invariably found in the immediate vicinity of human habitations (Adisubramaniam and Vedamaniklam, 1943) while in the Hazaribagh Ranges and Jey pore Hills, breeding in significant numbers was found even up to at least half a mile from human dwellings (Venkat Rao and Philp 1947)

BIONOMICS OF ADULTS

Adult resting places—In North Kanara, human habitations were observed to be the common resting places of *A. fluviatilis* (Jaswant Singh and Jacob 1944). Measham and Chowdhury (1934) in the Anaimallai Hills (Madras), collected only four specimens from cowsheds as compared to 199 from human dwellings. In Bombay state also where this species is an efficient vector, the fraction of the population that elects to remain indoors during the day is found almost exclusively in human dwellings, with only five per cent of the indoor population occupying cattle sheds (Viswanathan, 1950). *A. fluviatilis* is often found on lower portions of the walls, not more than five feet from the floor (Russell et al., 1946). Senior White (1941, 1946), Viswanathan and Ramachandra Rao (1943), Viswanathan et al (1944) and Issaris et al (1953) observed a significant fraction of the population resting outdoors during the day time in Satpura Ranges and Singhbhum Hills North Kanara (Bombay) and Uttar Pradesh Tarai, respectively. The outdoor resting places were found to be mainly on banks of streams where mosquitoes could find shelter under overhanging vegetation, projecting stones etc.

Biting Time—Viswanathan and Ramachandra Rao (loc cit) in North Kanara (Bombay), found that females *A. fluviatilis* entered a human shelter shortly after dusk and completed feeding before midnight in the main. Viswanathan et al (loc cit) in the same area observed that approximately 71 per cent of *A. fluviatilis* entered houses for feeding during the first quarter of the night, 19 per cent in the second, seven per cent in the third and three per cent in the last quarter. In Mysore State, however,

Nursing *et al* (1934) found nearly as many *A fluviatilis* entering houses after midnight as before. Senior White *et al*, (1945) in Jeypore Hills observed that the numbers entering between midnight and dawn were much greater than those entering before midnight and out of this 90 per cent of the females were either hungry or freshly fed. Similarly, Jaswant Singh and Mohan (1951) in the Nilgiris observed *A fluviatilis* feeding in all four quarters of the night, most of the activity being confined to the second and third quarters indicating a difference in behaviour from the early feeding mosquitoes in Bombay State.

• GONOTROPHIC CYCLE

Senior White *et al* (1945) in their laboratory studies on *A fluviatilis* from Jeypore Hills, found that with temperature varying between 26° and 19.5° C mosquitoes with one feed only, took 48 to 96 hours for complete development of ovaries and 72 to 120 hours for oviposition. Viswanathan *et al* (1944) in North Kanara (Bombay) found that this species had a 48 hour gonotrophic cycle from September to November and 72 hour cycle from December to February. The findings of Jaswant Singh and Mohan (*loc cit*) in the Nilgiris on the other hand indicated that certain proportion of the females required only a single blood feed for the maturation of their ova a further proportion required a double feed in one night or on successive nights within one gonotrophic cycle thereby demonstrating the existence of the phenomenon of gonotrophic discordance.

ANTHROPOPHILISM AND ZOOPHILISM

Out of 1681 specimens from the Wynad, an anthropophilic index of 97 per cent was obtained (Covell and Harbhagwan, *loc cit*). Jaswant Singh and Jacob (*loc cit*) observed that 63.6 per cent of the *A fluviatilis* captured from North Kanara (Bombay) had fed on human blood. Senior White (1947) found an anthropophilic index of 56.8 per cent in specimens caught from human dwellings in East Central India. Barber and Rice (1938) in Poona (Bombay) and Ramsay *et al* (1936) in Assam found that specimens containing human blood were 4.6 and 3.8 per cent respectively. *A fluviatilis* being primarily anthropophilic in some regions and zoophilic in others may be due to the fact that the species may be composed of two biological races which differ markedly as regards their preferential feeding tendencies. The anthropophilic index of *A*

fluviatilis from the U P Tarai was 1.8¹ and 1.4³ per cent in 1938 and 1939 respectively while it was found to be 47 per cent in 1949-52 (Ramakrishnan and Satya Prakash 1953). This marked change in the anthropophilic index in the course of about 10 years requires explanation. In the past, the region was densely wooded with little human population and highly malarious in spite of the fact that the anthropophilic index of *A. fluviatilis* was low. The forests have now been cleared, large areas drained and reclaimed for extensive agricultural operations. Greater opportunities exist now for a very much higher degree of mosquito man contact, than during the pre colonisation period (Ramakrishnan and Satya Prakash *loc cit*). With large scale indoor residual DDT spraying since 1947 in parts of U P Tarai it has been possible to colonise several thousands of people in the area (Srivastava, 1950). *A. fluviatilis* in this area may be a mixture of anthropophilic and zoophilic races. It is neither like the predominantly anthropophilic race of the Wynad nor the predominantly zoophilic race it was originally considered to be in 1938-39 (Issaris *et al*, *loc cit*).

FLIGHT RANGE

No records of observations on the flight range of freshly emerged *A. fluviatilis* from natural larval habitats are available. Adisubramaniam and Vedamanikkam (*loc cit*) in the Wynad area, found larvae of *A. fluviatilis* up to not more than a thousand feet from human dwellings and concluded that the species had a short range of flight in that area. Whereas Venkat Rao and Philip (*loc cit*) in Hazaribagh Ranges found breeding of *A. fluviatilis* up to at least half a mile from the feeding place and presumed this to be their usual flight range in search of food.

SURVIVAL OR LONGEVITY

Regarding survival of *A. fluviatilis* under field conditions there is no other record except that of Senior White *et al* (*loc cit*) who by release and recapture of marked mosquitoes in Jeypore Hills could follow up specimens for a period of 48 days. Under controlled laboratory conditions Pal (1943) found temperatures from 20° to 30°C and humidity from 50 to 80 per cent to be the optimum for the longevity of this species.

1 Annual report of the Malaria Institute of India 1938

2 Annual report of the Malaria Institute of India 1939

SWARMING

Mohan (1945) who studied the sexual behaviour of *A. fluviatilis* in captivity noticed that swarming and mating could be induced by the use of artificial blue light inside the cage. Subsequent studies showed that in warmer environment stimulus provided by blue light was not essential as swarming and mating took place in ordinary light and even in darkness (Mohan, 1951).

RELATION TO MALARIA

A. fluviatilis is a very important vector in the foothill regions of Peninsular India comprising portions of Madhya Pradesh, Travancore Cochin, Mysore, Madras and Bombay states and in East Central India. Mosquito dissection records so far available and the associated epidemiological data collected by various workers have been presented in Table I. Till recently *A. fluviatilis* in the north was considered of little importance as a vector. The only published records of natural infection of *A. fluviatilis* in North India appear to be those of Robertson (1910), at Saharanpur (Uttar Pradesh) who gave no details of his dissections, and Macdonald and Majid (1931) who reported two specimens with gut infection out of 23 dissected at Karnal. Clyde (1931) dissected 460 specimens at Banbassa (Tarai region of Uttar Pradesh) with negative results. In 1938¹ a team from the Malaria Institute of India working at Bazpur in the same area found two gut infections in the 1817 specimens dissected. Issaris *et al* (*loc cit*) however, in the same region found a gross sporozoite rate of 0.99 per cent during the years 1950-53 and incriminated *A. fluviatilis* as an important vector of the area. Available evidence would seem to indicate the possibility of the prevalence of more than one biological race of this species, judging from its different vectorial capacities in different parts of the country and the differences in its host predilection (Viswanathan, 1950). Brooke Worth and Sitaraman (1952) visualize two possible groups of *A. fluviatilis* (1) anthropophilic, outdoor resting, hill inhabiting, strongly vectorial and low in density and (2) zoophilic, indoor resting, plains inhabiting, weakly vectorial and high in density.

Usually hyperendemic conditions prevail in areas where, *A. fluviatilis* is a vector. Transmission with this species has been

¹ Annual Report of the Malaria Institute of India for the year 1938

reported almost all through the year, the actual transmission period varies in extent in different regions. Viswanathan (1946) has calculated that a density of 0.4 per man hour of *A. fluviatilis* is the level at which it can carry on effective transmission of malaria.

CONTROL

Larval control—Adisubramaniam and Vedamanikkam (*loc cit*) in the Wynaad recorded maximum density of *A. fluviatilis* larvae within 1000 feet of human habitations and found that antilarval measures like oiling of breeding places could be limited to places within 1000 to 1500 feet from human dwellings. Venkat Rao and Philip (*loc cit*) however, in Hazaribagh Ranges and Jeypore Hills found *A. fluviatilis* breeding in significant numbers up to at least half a mile from the place of feeding and concluded that antilarval operations against the species could not safely be limited to less than half a mile from the area to be protected. Subbaraman and Vedamanikkam (1943) in the Wynaad controlled the breeding of *A. fluviatilis* by clean weeding the margins of breeding places. In the same area Covell and Harbhagwan (*loc cit*) obtained encouraging results by herbage packing of the breeding places and recommended this as a cheap and effective method of malaria control.

The extent of breeding places of *A. fluviatilis* is so great and their antilarval treatment so difficult and costly that enforcement of antilarval measures for rural malaria control is almost impracticable. For efficient malaria control reliance has to be placed on anti-adult measures.

Anti-adult measures by pyrethrum spraying so successful against other species are not effective against *A. fluviatilis* except when the costly method of daily spraying is adopted (Viswanathan *et al.*, 1944, Senior White *et al.*, 1945). *A. fluviatilis* spends one day light period after feeding in the house and then leaves the house for some outdoor shelter to spend the remaining part of the gonotrophic cycle there irrespective of whether the cycle is completed in two, three or four days and is not always available when pyrethrum spraying is done (Venkat Rao, 1949). The only effective and economical anti-adult measure appears to be spraying of all houses with residual insecticides.

Senior White (1945) and Senior White and Ghosh (1946) in Jeypore Hills found that DDT spraying at 50 mg per sq ft gave

effective protection against *fluviatilis* malaria and they recommended its two monthly application during the transmission season. Viswanathan and Parikh (1946) and Viswanathan (1950) in Bombay, Ramakrishnan *et al* (1948) in South Kanara, Vedamanikkam (1949) in the Wynaad and Srivastava and Chakrabarti (1952) in Uttar Pradesh Tarai also controlled *fluviatilis* malaria effectively with DDT spraying at 50-56 mg DDT per sq ft repeated every 6 to 12 weeks. In view of the encouraging results obtained in different areas so far, it can be stated with confidence that *fluviatilis* malaria in rural areas can be controlled effectively and economically by indoor spraying of houses with DDT and other residual insecticides.

TABLE I

| Area | Spleen rate per cent | Parasite rate per cent | Dissection of A fluviatilis | | | Observer |
|--|-------------------------|---------------------------|-----------------------------|--------------------------------|--|--|
| | | | Oocyst rate per cent | Sporozoite rate per cent | Total infection rate per cent | |
| Jeypore Hills | — | — | — | 1.8 | 1.8 | Perry (1914) |
| Wynaad (Madras) | — | — | — | — | 6.6 | Horne (1914) |
| Mopad (Madras) | — | — | 3.9 | — | 3.9 | King and Iyer (1909) |
| Anaimallai Hills (Madras) | — | — | 6.4 | 3.9 | 8.8 | Measham and Chowdhury (1934) |
| South Travancore | — | — | 23.7 | 12.0 | — | Mathew (1934) |
| Wynaad (1938-39) | 56 to 69 | 17 to 56 | 16.0 | 7.6 | 20.2 | Covell and Har bhagwan (1939) |
| Nilgiris Distt (Madras) (1940-42) | 46.5 to 84.5 | 33.3 to 45.6 | 9.7 | 10.1 | 17.3 | Russell and Jacob (1942) |
| North Kanara (Bombay) (1942-43) | 42.7 | 14.9 | 6.2 | 7.1 | 11.0 | Jaswant Singh and Jacob (1944) |
| North Kanara (Bombay) | — | — | 29.6 | 37.0 | 44.4 | Viswanathan and Ramachandra Rao (1943) |
| Jeypore Hills (Orissa) (1944-46) | — | — | 3.8 | 2.6 | — | Senior White and Ghosh (1946) |
| Jeypore Hills and Hazaribagh Ranges (East Central India) | — | — | — | — | 5.7 | Senior White (1947) |
| South Kanara (Madras) (1947-48) | 63 to 76 | 3.6 to 29.3 | — | 2.7 | — | Ramakrishnan et al (1948) |
| Khandwa (M P) | — | — | — | 1.28 | — | Subramanian and Dixit (1943) |
| Bombay State Kanara Distt (1943) | — | — | — | — | 7.0 | Viswanathan (1950) |
| Nasik Distt (1947-49) | — | — | — | — | 0.2 | do |
| Panch Mahals Distt (1948-49) | — | — | — | 0.8 | 0.8 | do |
| Poona and Sholapur Distts (1948-49) | — | — | — | 0.11 | 0.11 | do |
| Kolaba Distt | — | — | 0.44 | — | 0.44 | do |
| Tarai Nainital Distt (U P) | — | — | — | 0.09 | — | Issaris et al., (1953) |
| Tarai Nainital Distt (U P) (1949) | — | — | — | 11.1 | — | Srivastava and Chakrabarti (1952) |
| Tarai Nainital Distt (U P) (1951) | — | — | — | 1.6 | — | do |

REFERENCES

- Ad subramaniam T S and Vedamanikam J C (1943) *J Mal Inst* 5, p. 53-58
- Barber M A and Rice J B (1931) *Ibid* 1 p 37-52
- Brooke Worth C and Saraman M L (1952) *Ind J Mal* 6 p 491-491
- Burke M R (1937) *J R A M C* 69 p 115 and 84-85
- Covell G (1927) *Ind Med Res Mem* No. 5 p. 1-85
- Idem* (1931a) *Rec Mal Surv Ind* 2 p 225-268
- Idem* (1931b) *Health Bull* No 17 Government of India Central Publication Branch Calcutta
- Idem* (1944) *J Mal Inst Ind* 5 p. 399-434
- Covell G and Harbhagwan (1939) *Ibid* 2 p. 341-376.
- Cyde D (1931) *Rec Mal Surv Ind* 2 p. 49-110
- Horne J H (1914) *Surp Ind J Med Res* 4 p 71-74
- Issaris P C, Rastogi S N and Ramakrishna V (1953) *Bull Wild Hlth Orgn* 9 p 311-333
- Jaswant Singh and Jacob V P (1944) *J Mal Inst Ind* 5 p 267-303
- Jaswant Singh and Mohan B N (1951) *J Mal* 5 p 513-525
- King H H and Iyer M K R (1929) *Spp Ann Rep Kng Inst Gundy* 1927-29 10-11
- Macdonald G and Majid A (1931) *Rec Mal Surv Ind* 2, p. 423-480.
- Mathew M I (1934) *J Mal Inst Ind* 2 p 101-104
- Measham J E and Chowdhury M U (1934) *Rec Mal Surv Ind* p 363-365
- Mohan B N (1946) *J Mal Inst Ind* 6 p. 75-76
- Idem* (1951) *Nature* 169 p. 280
- Nursing D, Rao B A and Sweet W C (1934) *Rec Mal Surv Ind*, 4, p 243-251
- Pal R (1943) *J Mal Inst Ind* 4 p. 251-253
- Perry E. L. (1914) *Ind J Med Res* 2 p 455-491
- Puri, I M (1930) *Rec Mal Surv Ind*, 6 p 177-211
- Idem* (1948) *Ind J Mal* 2, p. 67-107
- Ramschandra Rao T (1945) *J Mal Inst Ind* 6 p. 77-82
- Ramakrishnan S P, Krishnan K S and Ramakrishna V (1948) *Ind J Mal* 2 p 247-282
- Ramakrishnan S. P and Satya Prakash (1953) *Ibid* 7 p 107-112
- Ramsay G C, Chandra S N and Lamprell, H A (1956) *Rec Mal Surv Ind* 6, p 49-52
- Rbertson, J C. (1910) *An inquiry into malaria in Saharanpur City* Government Press, Allahabad
- Russell P F and Jacob V P (1942) *J Mal Inst Ind* 4 p. 349-392
- Russell P F, Rozeboom L E and Stone, A. (1943) *Key to the anopheline mosquitoes of the world* American Entomological Society Academy of Natural Sciences, Philadelphia

- Russell P F, West L S and Manwell R D (1946) *Prac Malarology* W B Saunders Co, Philadelphia and London
- Senior White R (1941) *J Mal Inst Ind*, 4, p 57 62
- Idem* (1945) *Ibid* 6 p 83 93
- Idem* (1946) *Ibid* p 425 435
- Idem* (1947) *Ind J Mal*, 1 p 111 122
- Senior White R and Ghosh A K (1946) *J Mal Inst Ind* 6 p 489 508
- Senior White, R, Ghosh A K and Venkat Rao V (1945) *Ibid*, p 129 215
- Srivastava K S (1950) *Ind J Mal*, 4 p 151 165
- Srivastava, K S and Chakrabarti A K (1952) *Ibid*, 6 p 381 394
- Subbaraman A K and Veda manikkam, J C (1943) *J Mal Inst Ind* 5, p 113 115
- Subraman an, R and Dixit D T (1948) *Ind J Mal* 2, p 313 322
- Vedamanikkam, J C (1949) *Ibid*, 3 p 121 338
- Idem* (1952) *Ibid*, 6 p 367 376
- Venkat Rao V (1949) *Ibid*, 3 p 313 326
- Venkat Rao, V and Phil p, M I (1947) *Ibid*, 1 p 37 41
- Viswanathan, D K (1946) *J Mal Inst Ind*, 6, p 253 257
- Idem* (1950) *Malaria and its control in Bombay State* Chitrasahala Press, Poona
- Viswanathan D K and Parikh R O (1946) *J Mal Inst Ind* 6 p 383 391
- Viswanathan D K and Ram chandra Rao T (1943) *Ibid* 5 p 255 260
- Viswanathan D K, Rama Chandra Rao T and Rama Rama Rao T S *Ibid*, 5, p 449 466.

VI *A MINIMUS* THEOBALD, 1901

BY

A K KRISHNASWAMI

(Malaria Institute of India Delhi)

[June 21 1953]

AN important malaria carrier of the submontane regions of Eastern India is *A minimus*. The type form of this species is the chief vector in the foothill regions and plains of northern Bengal and Assam and is responsible for hyperendemic conditions often associated with black water fever and pernicious type of malignant tertian malaria (Covell 1949). Though recorded from various parts of central and peninsular India its vectorial status has not been established in these parts. *A minimus* is one of the few anophelines of India which have been studied in great detail.

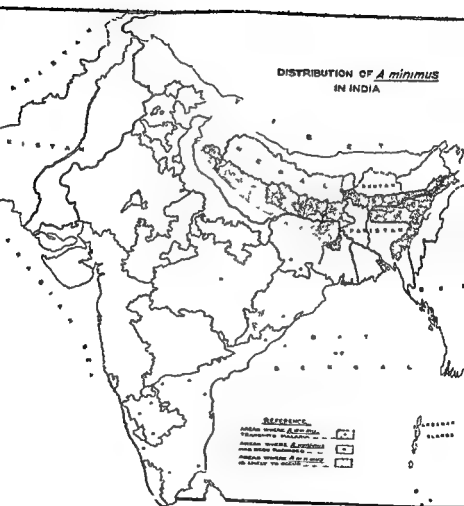
A minimus var *flavirostris* (Ludlow 1914) the principal vector in the Philippines (Russell 1933) has not been recorded in this country.

DISTRIBUTION

A minimus has a wide distribution both in the north and peninsular parts of India (Map 5). The species has been recorded from Assam W Bengal Bihar Uttar Pradesh Chota Nagpur Konkan Hyderabad, Madras Mysore and Malabar.

LARVAL HABITATS

Continuous breeding of *A minimus* has been observed only in clear unpolluted slow moving water with grassy edges (Covell 1944). Manson and Ramsay (1933) observed that clear running water with plenty of swamp vegetation and very little shade were best suited to breeding of *A minimus*. They also found that fallow but not ploughed up fields were favourable to breeding of this species. Thomson (1940) observed that stagnant places like marshes and ricefields were of no importance as breeding places. In the latter however the presence of larvae may be encountered due to drift from irrigation channels. He further observed that larval prevalence in a breeding place was entirely due to selection of it by the gravid female which prefers to deposit its eggs in shady portions. The shade is usually provided by marginal vegetation. More recently Thomson (1951) carried out crucial experiments both in the field and laboratory to determine the exact role played by the grassy edge. He concluded that the grass apart from providing shade played an



additional role in creating a zone of still water. Full grown larvæ of *A. minimus* were unable to resist a current of 0.20 to 0.31 ft. per second (Thomson, 1940). Dark shady crab holes on the margins of streams without flowing water even in the absence of any vegetation, may form dangerous breeding places and can be overlooked. In some foot hill areas *A. minimus* was also found breeding in clean waters of shallow earth wells (Thomson, 1951).

BEHAVIOUR OF THE ADULT MOSQUITO

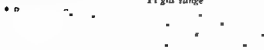
Daytime resting places—In North Bengal and Assam *A. minimus* is a domestic species resting mainly in houses. Manson and Ramsay (1932) found that 98.2 per cent of their collection of this species were from human habitations. Thomson (1941) observed that this species rested mainly in the lower half of the walls often on the floor under cots. A striking observation of Thomson (1941) was the patchy distribution of *A. minimus* in houses some houses always yielding large numbers—due either to their location or their special suitability as resting places.

A. minimus has been reported to be a chiefly outdoor restor in China (Chang 1939 quoted by Covell 1944). In India S. N. White Ghosh and Rao (1945) collected *A. minimus* from outdoor shelters among rocks near a stream in Jeypore Hill Tracts. It could only be speculated at this stage whether this variation in resting habits of *A. minimus* in different parts indicates the existence of more than one distinct biological variety.

FEEDING TIME

Thomson (1941) observed complete absence of blood fed specimens among *A. minimus* collected before 10.30 p.m. and concluded that most of the feeding took place after that time. Krishnaswami (1952) confirmed these observations and found that the main feeding activity took place after midnight in the third and fourth quarters of the night.

Flight range



that the nearest breeding place of *A. minimus* was within two miles of the diurnal resting place and considered the flight range to be not less than one thousand yards. According to the experience of the workers in the Malaria Institute of India, Delhi the flight range of *A. minimus* in Assam and foot hills of West Bengal can be broadly taken as half a mile.—Ed.

By carefully designed marking experiments, Thomson (1941) recorded that females returned on the night of oviposition to the same house or group of houses for their next blood feed

Gonadotropic cycle — In the plains of Assam during hot damp season, *A. minimus* was found to take two days to digest its blood meal as well as for the complete development of ovaries and oviposition (Thomson, 1941). In cold weather, however, this period was increased to 4-6 days

Senior White *et al* (*loc. cit*) observed in the Jeypore Hill Tracts that ovarian development took 72-96 hours, and that the completion of this cycle was more of an outdoor phenomenon

Feeding, digestion of blood and maturation of ovaries followed by oviposition continued right through the cold weather and no hibernation of females of *A. minimus* was recorded in the plains of Assam (Rice and Mohan, 1936). This finding was confirmed by Thomson (*loc. cit*)

Food preference — *A. minimus* of north and east India is mainly a domestic species with a high preference for human blood. Ramsay *et al* (1936) recorded the anthropophilic index as 85.7 per cent, while Senior White *et al* (*loc. cit*) found the rate to be 92.4 per cent for the same species in the Jeypore Hill Tracts of Orissa. Comparatively low anthropophilic indices ranging from 31 to 41 per cent were recorded for *A. minimus* from Central Burma (Malaria Institute of India unpublished records). Among the blood meals of *A. minimus* from Thailand, analysed at the Malaria Institute of India, 37 per cent were positive for human blood during the period October, 1949 to April, 1950 while the index for the period Aug—Sept 1949, was 71.2 per cent

Thermal death point — Exposure for a period of 5 to 10 minutes at temperatures ranging between 37° and 38°C was fatal to majority of females of *A. minimus* (Thomson, 1940). Variation in humidity did not alter the mortality rate

Longevity — Senior White *et al* (*loc. cit*) was able to follow up such specimens for a period of 19 days, by release and recapture of marked specimens. Thomson (1941) observed that the survival rate was longer during the humid part of the year following the rains than during the hot dry pre monsoon period

EPIDEMIOLOGICAL FEATURES

Data collected by different workers on the various epidemiological aspects of *minimus* malaria during the last two decades have been presented in Table I

TABLE I

Observations on the epidemiological aspects of minimus malaria

| Area | Spleen rate per cent | Parasite rate, per cent | Dissections of <i>A. minimus</i> | | | Observer |
|----------------|----------------------|-------------------------|----------------------------------|-----------------|----------------------|--------------------------------|
| | | | Oocyst rate | Sporozoite rate | Total infection rate | |
| Bengal | — | — | 11.6 | 9.3 | 18.6 | Iyengar (1940) |
| Assam | 8.2 | 35.8 | — | 1.8 | — | Viswanathan (1941) |
| Jeypore III Ia | — | — | — | 4.4 | — | Sen or White (1945) |
| Bengal | — | — | — | 3.1 | — | Puri and Krishna Swami (1947) |
| Assam | — | — | — | — | 4.67 | Manson and Ramsay (1932) |
| Assam | 57.0 | 45.0 | — | — | — | Macdonald and Chowdhury (1931) |
| Assam | 85.2 | 70.0 | 8.13 | 0.89 | — | Gupta <i>et al.</i> (1932) |
| Assam | 55.0 | 59.0 | — | — | 6.2 | Rice and Savage (1932) |
| | 10 | 10 | | | | |
| | 73.0 | 68.0 | | | | |
| Assam | — | 44.4 | 1.4 | 2.1 | — | Manson and Ramsay (1935) |
| Assam | — | — | 4.4 | 1.3 | 5.56 | Gupta <i>et al.</i> (1935) |
| Assam | — | — | — | — | 2.7 | Lamprell (1936) |
| Assam | 90.86 | 69.13 | 0.67 | 0.67 | 1.35 | Paul <i>et al.</i> (1936) |
| Assam | 68.0 | 49.0 | 8.3 | 1.4 | 8.3 | Gilroy (1939) |
| Assam | — | — | 2.0 | 3.0 | 5.0 | Khan (1942) |
| Bengal Dooars | 74.8 | 35.0 | — | 0.82 | — | Ray (1943) |
| The land | — | — | 0.93 | 2.47 | 3.14 | Bhatia (1953) |

Parasite and spleen rates—Hyperendemic conditions prevail in areas where *A. minimus* is responsible for malaria transmission. Spleen rates as high as 80-90 per cent and parasite rates of 50-70 per cent (Table I) have been recorded.

Species plasmodia—Though *P. falciparum* is the predominating species, all the three common human plasmodia occur (Jaswant Singh *et al.*, 1952).

Infection rates in A. minimus—The highest infection rates among *A. minimus* have been recorded by Iyengar (1940) a total with 20 gut and 16 gland infections among 172 specimens dissected giving rise to 18.6 per cent infection rate.

Season—Transmission has been reported almost all the year round except during the months January to April. Viswanathan (1941) obtained gland infections from June to December in Assam. Macdonald and Chowdhury (1931) also in Assam recorded positive dissections from May to December while Iyengar (1940) working in Bengal found transmission during June to September only.

Altitude—Khan (1942) recorded positive dissections of *A. minimus* at a height of 1,200 ft above sea level on the Darjeeling hills.

CONTROL

Larval control—The specialised nature of the breeding places selected by *A. minimus* has been exploited by different workers in devising means for its control during its aquatic stages. Manson and Ramsay (1932) stressed the value of silting as a direct anti larval measure against *A. minimus*. Diversion of silt laden streams into dangerous breeding places like 'Bhils' or marshes was proved to be an ideal method of controlling breeding of *A. minimus* (Strickland and Murphy 1932).

Shading especially of streams which are the sanctuaries of *A. minimus* has been effectively utilised to control the breeding of this species. Thomson (1940) studied the problem in detail and observed the total shading was necessary to ensure proper control. He found that this method did not immediately put a stop to the breeding but on the contrary resulted in increased intensity of breeding. When, however, marginal vegetation was removed an immediate reduction in the larval density was noticed. Though oviposition was not hampered as shown by the continued presence of eggs and first stage larvæ it was concluded that shade *per se* played no part in the control of *A. minimus*, but the absence of larvæ is mainly due to the secondary changes, chiefly the elimination of marginal vegetation which resulted in (a) increased velocity of flow at the edges (b) reduction of the available food for larvæ (Thomson 1951).

Anti adult measures—Viswanathan (1941) reported reduction in sporozoite rates to 5 per cent (comparison area 18 per cent) by weekly spraying of pyrethrum at one ounce per 1,400 c. ft. in the huts in tea estates of Assam. By spraying twice a week the

infection rate among mosquitoes was reduced to zero (Viswanathan, 1942)

Based on the observation that this species mainly rests on the lower surface of the walls Weeks (personal communication) carried out field experiments in Burma to see if *A. minimus* could be controlled by spraying the walls upto three feet from the ground only. No appreciable reduction in mosquito population was noticed following the operation.

Puri and Krishnaswami (1947) reported control of *minimus* malaria by residual spraying with DDT at 60 and 120 mg per sq ft in the coolie huts of the tea gardens of Darjeeling Terai. The residual effect of such doses was found to last over 8-12 weeks.

Bertram (1950) recorded a high survival rate among *A. minimus* from DDT sprayed houses and suggested that this species escaped from acquiring the lethal dose due to the excito-repellent action of the insecticide. Macdonald (1950) discussing the observations of Gilroy in Assam reported 100 per cent mortality among *A. minimus* trapped from treated houses. Evidence supporting that *minimus* malaria was controlled in the Darjeeling Terai by indoor residual spraying with DDT was recorded by Krishnaswami (1952).

It can be stated that *A. minimus* a vector of great importance is almost confined to rural areas in the foothill regions of India. The control method of choice in such areas is the indoor residual spraying of DDT and the available evidence indicates that *minimus* malaria is amenable to control by this method.

REFERENCES

- | | | |
|----------------------------------|--------|--|
| Bertram D M | (1950) | <i>Ann Trop Med Parasit</i> 41, p 242 |
| Chattopadhyay M L | (1953) | <i>Personal communication</i> |
| Covell G | (1944) | <i>J Mal Inst Ind</i> 5, p. 399 |
| Idem | (1949) | <i>Malariaology</i> 2 # 810 (Edited by Boyd M F) W B Saunders Co Philadelphia and London |
| Craig C | (1919) | Reported by Boyd 1947 |
| Gilroy A | (1949) | <i>J Mal Inst Ind</i> 2, p. 165 |
| Gupta P, Das G and Majumdar, N R | (1932) | <i>Rec Mal Surt Ind.</i> 3, p. 253 |
| Idem | (1933) | <i>Ibid</i> , p. 845 |
| Harrison, C. C. and Ramsay, G C | (1931) | <i>Jour Trop Med Hyg</i> 36 33 |

| | | |
|---|---------|---|
| Iyengar M O T | (1940) | <i>J Mal Inst Ind</i> , 3, p 115 |
| Jaswant Singh Krishna swami A K and Ramakrishnan, B P | (1952) | <i>Ind J Mal</i> , 6, p 4 |
| Khan B M | (1942) | <i>J Mal Inst Ind</i> , 4, p 421 |
| Krishnaswami, A K | (1952) | <i>Ind J Mal</i> , 6, p 117 |
| Lamprell, B A | (1936) | <i>Rec Mal Surv Ind</i> , 6, p 213 |
| Macdonald, G | (1950) | <i>Brit Med J Aug 12th</i> , p 414 |
| Macdonald G and Chowdhury K L | (1931) | <i>Rec Mal Surv Ind</i> , 2, p 111 |
| Manson D and Ramsey G C | (1932) | <i>Rec Mal Surv Ind</i> , 3, p 143 |
| <i>Idem</i> | (1933) | <i>Ibid</i> , p 479 |
| Paul S H, Das, G S, and Roy S C. | (1936) | <i>Ibid</i> , 6, p 483 |
| Puri I M and Krishna swami, A K | (1947) | <i>Ind J Mal</i> , 1, p 159 |
| Ramsay, G C Chandra B N and Lamprell, B A | (1936) | <i>Rec Mal Surv Ind</i> , 6, p 49 |
| Ray, A P | (1948) | <i>Ind J Mal</i> , 2, p 35 |
| Rice E M and Savage J de la M | (1932) | <i>Rec Mal Surv Ind</i> , 3 p 219 |
| Rice E M and Mohan B N | (1936) | <i>Ibid</i> , 6, p 557 |
| Russell P F | (1933) | <i>Science</i> , 78 p 101 |
| Russell, P F and Santiago D | (1934a) | <i>Am J Trop M</i> 14 2 p 139 |
| <i>Idem</i> | (1934b) | <i>Ibid</i> 14 p 40 |
| Senior White R, Ghosh A R and Rao, V V | (1945) | <i>J Mal Inst Ind</i> , 6 p 125 |
| Strickland C and Murphy R A | (1932) | <i>Rec Mal Surv Ind</i> , 3, p 125 |
| Thomson, R C M | (1940) | <i>J Mal Inst Ind</i> , 3, p 295 |
| <i>Idem</i> | (1941) | <i>Ibid</i> , 4, p 217 |
| <i>Idem</i> | (1951) | <i>Mosquito Behaviour</i> Edward Arnold & Co, London |
| Viswanathan, D K | (1941) | <i>J Mal Inst Ind</i> , 4, p 35 |
| <i>Idem</i> | (1942) | <i>Ibid</i> , 4, p 193 |
| Weeks, E B | (1953) | <i>Personal communication</i> |

VII A VARUNA IYENGAR 1924

BY

V VENKAT RAO

(August 17 1954)

A VARUNA, one of the members of what is commonly described as the '*fluviatilis* group'*, was treated as a variety of *A. minimus* or some times referred to as *A. listoni* (*A. fluviatilis*) before its isolation as a distinct species by Iyengar (1924). The position, however, continued to be somewhat confused for a few years more till it was clarified by Christophers and Puri (1931). Records of *A. minimus*, and sometimes of *A. fluviatilis*, pertaining to the period prior to about 1930 are, therefore, likely to refer to *A. varuna* in certain areas.

Contrary to earlier observations, *A. varuna* is now known to be a vector of only local importance in some areas, particularly in the hill tracts of East Central India. Elsewhere, it may be a vector of minor importance as in Bengal (Iyengar, 1942) or a perfectly harmless *Anopheles* as in the Vizagapatam area (Senior White and Venkat Rao, 1943). However, in the areas of its importance, it is seen to be a powerful vector with infection rates as high as four per cent or more but, even in such areas, it always exists in association with *A. fluviatilis* and *A. minimus*, except in the Hazaribagh and Eastern Satpura ranges where it exists with *A. fluviatilis* alone. There is practically no locality in the Indian region where *A. varuna* holds the field as the sole vector.

DISTRIBUTION

A. varuna has been found in Assam, Bengal, Bihar, Bombay, Gujerat, Konkan, Madras, Malabar, Mysore, Orissa, Travancore and Uttar Pradesh. It has also been found in the Madhya Pradesh (Senior White and Adhikari, 1940). Outside India, it has been recorded from Burma, specially hill tracts, S. China and Ceylon (Map 6).

*The three species viz., *A. fluviatilis*, *A. varuna* and *A. minimus* constitute this group. Some records refer to them as the '*funestus* group' owing to their close resemblance to *A. funestus*, an African species.

- Iyengar M O T (1940) *J Mal Inst Ind*, 3, p 115.
- Jaswant Singh Krishna swami A K and Ramakrishnan S P (1952) *Ind J Mal* 6, p 4
- Khan B M (1942) *J Mal Inst Ind* 4, p 421
- Krishnaswami, A K (1952) *Ind J Mal* 6, p 117
- Lamprell, B A (1936) *Rec Mal Surv Ind* 6, p 213
- Macdonald, G (1950) *Brit Med J Aug* 12th, p 414
- Macdonald, G and Chowdhury K L (1931) *Rec Mal Surv Ind* 2 p 111
- Manson D and Ramsay G C (1932) *Rec Mal Surv Ind* 7, p 143
- Idem* (1933) *Ibid* p 479
- Paul S H, Das, G S, and Roy S C (1936) *Ibid*, 6, p 483
- Puri I M and Krishna swami, A K (1947) *Ind J Mal*, 1, p 159
- Ramsay, G C Chandra, S N and Lamprell, B A (1936) *Rec Mal Surv Ind*, 6, p 49
- Ray, A P (1948) *Ind J Mal* 2, p 35
- Rice, E M and Savage J de la M (1932) *Rec Mal Surv Ind*, 3 ■ 219
- Rice E M and Mohan B N (1936) *Ibid*, 6 p 557
- Russell P P (1933) *Science*, 78, p 101
- Russell, P P and Santiago D (1934a) *Am J Trop M* 14 2 p 139
- Idem* (1934b) *Ibid* 4 p 40
- Senior White, R, Ghosh A R and Rao, V V (1945) *J Mal Inst Ind*, 6 ■ 125
- Strickland C and Murphy, R A (1932) *Rec Mal Surv Ind*, 3, p 125
- Thomson, E C M (1940) *J Mal Inst Ind*, 3, p 295
- Idem* (1941) *Ibid* 4 p 217
- Idem* (1951) *Mosquito Behaviour*, Edward Arnold & Co, London
- Viswanathan, D K (1941) *J Mal Inst Ind* 4, p 35
- Idem* (1942) *Ibid*, 4, p 393
- Weeks, E B (1953) *Personal communication*

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V VENKAT RAO

(August 17, 1954)

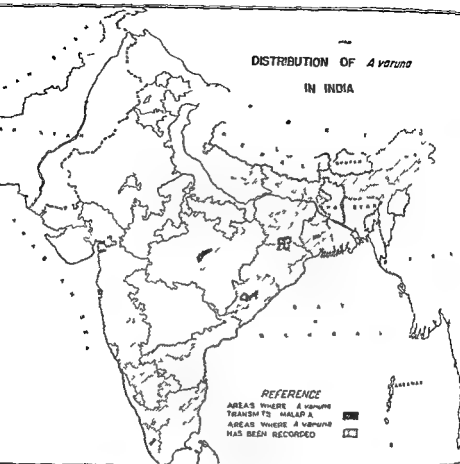
A *VARUNA*, one of the members of what is commonly described as the '*fluviatilis* group'*, was treated as a variety of *A. minimus* or some times referred to as *A. listoni* (*A. fluviatilis*) before its isolation as a distinct species by Iyengar (1924). The position, however, continued to be somewhat confused for a few years more till it was clarified by Christophers and Puri (1931). Records of *A. minimus*, and sometimes of *A. fluviatilis*, pertaining to the period prior to about 1930 are, therefore likely to refer to *A. varuna* in certain areas.

Contrary to earlier observations, *A. varuna* is now known to be a vector of only local importance in some areas particularly in the hill tracts of East Central India. Elsewhere, it may be a vector of minor importance as in Bengal (Iyengar, 1942) or a perfectly harmless *Anopheles* as in the Vizagapatam area (Senior White and Venkat Rao 1943). However, in the areas of its importance it is seen to be a powerful vector with infection rates as high as four per cent or more but, even in such areas, it always exists in association with *A. fluviatilis* and *A. minimus*, except in the Hazaribagh and Eastern Satpura ranges where it exists with *A. fluviatilis* alone. There is practically no locality in the Indian region where *A. varuna* holds the field as the sole vector.

DISTRIBUTION

A. varuna has been found in Assam, Bengal, Bihar, Bombay, Gujerat, Konkan, Madras, Malabar, Mysore, Orissa, Travancore and Uttar Pradesh. It has also been found in the Madhya Pradesh (Senior White and Adhikari, 1940). Outside India, it has been recorded from Burma, specially hill tracts, S. China and Ceylon (Map 6).

*The three species viz. *A. fluviatilis*, *A. varuna* and *A. minimus* constitute this group. Some records refer to them as the '*funestus* group' owing to their close resemblance to *A. funestus*, an African species.



Map 6
BREEDING PLACES

Iyengar (*loc cit*) found *A. varuna* breeding in stagnant fresh water in ponds and ditches and, during and soon after the monsoon in collections of storm water around Calcutta. Roy (1938) found *A. varuna* breeding in stagnant water collections in association with algæ and other aquatic vegetation and with overhanging shade. Puri (1931) found the larvæ in slow running streams and in wells in North Kanara District of Bombay. In Vizagapatam area, *kutch* wells (without any masonry steining) were observed to be the most favoured habitats and accounted for about 60 per cent of the total collection of 6,502 *varuna* larvæ, the next best habitat being small slow running streams with plenty of overhanging

shade (Senior and Venkat Rao 1943) Russell and Rao (1940) observed that the irrigation as well as household wells were preferred breeding places of this species Senior White (1946) observed that seepage ricefields of the hill tracts in East Central India were very favourable for the breeding of *varuna* and of the other two species of this group On the Orissa Coastal Plain, Senior White *et al* (1943) observed breeding in some weed covered tanks but the intensity of breeding increased after the tanks were clean weeded Venkat Rao and Ramakrishna (1940) found larvæ on many occasions in somewhat dirty and foul-smelling stagnant waters at Bhadrak in Orissa A *varuna* is thus seen to be capable of breeding in almost any type of water

Resting places—Adults of this species are according to Christophers (*loc cit*) frequently found in houses and cowsheds Senior White (1937) observed that in Jeypore Hills human habitations were preferred to a much greater extent than cowsheds for daytime resting The respective proportions of three species of the area in houses and cowsheds are as shown below —

ADULT HABITS

| | |
|------------------------|-----------|
| <i>A. culicifacies</i> | 10 to 30 |
| <i>A. funestus</i> | 60 to 100 |
| <i>A. jeyporiensis</i> | 10 to 65 |

From these observations, Senior White (*loc cit*) concluded that in that area '*funestus*' is dominantly attracted to human habitations and only overflowed into cowsheds during the peak months Further observations covering a period of one year more in the same area fully confirmed this conclusion (Senior White 1938) He included three species viz *A. fluviatilis*, *A. varuna* and *A. minimus* under the '*funestus*' group which makes it difficult to calculate the actual number of *varuna* involved in his studies However he specifically stated that he combined the three species into one group because he found no significant differences in their breeding habits and infection rates and that for all practical purposes they might be considered together He dissected among others 1877 *fluviatilis*, 542 *varuna* and 396 *minimus* most of which were collected from human habitations If the three species in the adult collections referred to above are also in the same proportions there must be among them 230 *varuna* in houses and

36 in cowsheds which shows that over six times as many *varuna* are attracted to houses as to cowsheds

Comparing the house and cowshed collections of Singbhum Hills, Senior White and Das (1938) found that '*funestus*' was attracted almost exclusively to houses there, the proportion being 48 in houses to one in cowsheds. Here too, their remarks are presumed to apply to *A. varuna* also

The observations made by Senior White and Adhikari (1949) in the Eastern Satpuras constitute a landmark in the studies on *A. varuna* as they indicate for the first time its potential outdoor resting tropisms. They examined 108 breeding places and collected 136 *fluviatilis* and 503 *varuna* larvæ but the corresponding adult catch of both the species was only 36. While *varuna* was three times as common as *fluviatilis* in the breeding places it was more than three times less plentiful in houses and therefore they made the cautious but pointed remark that there was much more breeding of both the species than house catches indicated

Around Vizagapatam there is prolific breeding of *varuna* but the adults were exceedingly rare in houses and cowsheds. Vigorous searches made in outdoor shelter such as the sides of running streams and *kutchas* wells and in thick scrub jungle in the vicinity of the breeding places were invariably negative, which led to special methods being devised. A casual observation revealed that, if *varuna* was very rare in houses and ordinary cowsheds it could be collected in numbers in those cowsheds which exist in fields away from houses and which are constructed entirely of palmyra thatch with the roof brought down save at the entrance to about a foot of the ground level. Such cowsheds are by no means rare in this particular area and may be seen dotted all over the country side. In order to carry out a comprehensive study of *varuna* which, on purely epidemiological grounds was suggested to be a non vector by the present author, two contiguous huts of the above type were constructed, the only modification effected being that the roof was brought down to the ground level and embedded in an earth ridge with a view to prevent the movement of mosquitoes from one shed to another during the night except through the open front door. One hut was human baited and the other buffalo baited. Catches were made to 'emptying' daily for 12½

months in the former hut and for 16 months in the latter. By this means, over 11,000 *varuna* were captured, 762 from the human-baited hut and 10 567 from the other (Senior White and Venkat Rao, 1943). It was thus shown that, in this area, *A. varuna* had special and somewhat peculiar resting habits which involve, not houses or ordinary cowsheds or even outdoor shelters, but a special type of cowsheds situated away from houses.

Pursuing his studies in the Eastern Satpura, Senior White (1941) produced presumptive evidence that *A. fluviatilis* must be resting outdoors to an appreciable extent in that area. As, during the study period, *A. varuna* became extremely rare its outdoor resting habits could not be elucidated at the same time. Some evidence of the exophily of *fluviatilis* soon became available from another quarter. Working in the Bombay State with stained mosquitoes, Viswanathan *et al* (1944) observed that 60 per cent of *fluviatilis* in the warm weather and 40 per cent in cool weather left their breeding places in human habitations for outdoor shelters. The position was further clarified by Senior White *et al* (1945) through their work in Singhbhum Hills. During the four months of their study beginning in September they collected 90 *varuna* in unsprayed houses, 66 in sprayed houses and no less than 2188 from outdoor shelters, which, in this area were the steep side of small running streams, not far away from the villages. The corresponding *fluviatilis* collections were 3 649, 151 and 91 respectively which clearly brings out the divergence in the adult bionomics of these closely related species. Thus, though *varuna* represents no more than 2.5 per cent of the *fluviatilis* group population in unsprayed houses, it forms 96 per cent of the outdoor resting population of the same group. Studying the wing and abdominable stages of the anopheline population in Jeypore Hills the same authors came to the conclusion that the *fluviatilis* group (including *varuna*) leave the house for outdoor shelters when the gonotrophic cycle is but half completed unlike *culicifacies* which rests at the feeding place till the digestion is almost complete. Evidently, there is much outdoor resting by *varuna* in this area too.

The above account shows that the resting habits of *A. varuna* vary a great deal in different areas or even within the same area itself.

Feeding time—The only record of feeding time of *A. varuna* available to the author is that of Senior White *et al* (1945), in which they stated that numbers of the *fluviatilis* group (including *varuna*) entering houses between midnight and 5 a.m. are much greater than those entering before midnight. The majority of this group in these collections were however *A. fluviatilis* only small numbers of *varuna* and *minimus* being encountered but appears to be no ground to assume that the behaviour of *varuna* is different in this respect from *fluviatilis*, at least in the Jeypore Hills.

Food preferences—It might be easy in the case of several anophelines to show that they are mainly or predominantly either anthropophilous or zoophilous. The results of precipitation tests for some common species obtained by Senior White (1947) which are shown in Table I illustrate the point.

TABLE I
Result of precipitation tests of some anophelines

| Species | Houses | | | Cowsheds | | | Out of Doors | | |
|------------------------|--------|-----|------|----------|-----|------|--------------|-----|------|
| | No + | M + | A I | No + | A I | M + | No + | M + | A I |
| <i>A. culicifacies</i> | 364 | 62 | 11.0 | 1404 | 194 | 13.8 | 62 | 5 | 8.1 |
| <i>A. annularis</i> | 430 | 13 | 3.0 | 1013 | 9 | 0.9 | — | — | — |
| <i>A. pallidus</i> | — | 1 | 1.1 | 326 | 3 | 1.1 | — | — | — |
| <i>A. aconitus</i> | 14 | 4 | 28.6 | 145 | 21 | 14.5 | 22 | 3 | 13.7 |
| <i>A. jeyporensis</i> | 26 | 6 | 23.1 | 314 | 27 | 8.6 | 37 | 1 | 2.7 |

No + = number positive

M + = Number positive for man

A I = anthropophilous index

The anthropophilous indices in the above cases are within certain limits similar, showing that the anophelines concerned are zoophilous either mainly or predominantly, whatever their resting places may be. In the case of *fluviatilis* or *minimus* from East Central India it could be stated that with a few exceptions which will be explained later they show marked evidence of anthropophilism. *A. varuna* however shows somewhat complex preferences. There is no doubt that generally in the hill tracts of East

Central India *varuna* rates high as a vector or rather as a co-vector, along with *A. fluviatilis* and *A. minimus* and should thus be equally anthropophilic. But even in these areas, there are certain variations (Table II).

TABLE II

Results of precipitation tests of *fluviatilis* group from various localities in East Central India

| Species | Locality | Houses | | | Cowsheds | | | Out of doors | | |
|-----------------------|-----------------|--------|------|-------|----------|------|-------|--------------|------|-------|
| | | No. + | M. + | A. I. | No. + | M. + | A. I. | No. + | M. + | A. I. |
| <i>A. fluviatilis</i> | Jeypore Hills | 357 | 295 | 82.6 | 14 | 9 | 64.3 | 27 | 25 | 92.6 |
| | Singhbhum Hills | 321 | 222 | 69.2 | 362 | 33 | 9.1 | 12 | 4 | 33.3 |
| <i>A. minimus</i> | Jeypore Hills | 124 | 112 | 90.3 | 9 | 6 | 67.7 | 5 | 5 | 100.0 |
| | Singhbhum Hills | 234 | 174 | 74.4 | 28 | 5 | 17.9 | 4 | 3 | 75.0 |
| <i>A. varuna</i> | Jeypore Hills | 96 | 78 | 81.2 | 22 | 14 | 63.6 | 7 | 6 | 85.7 |
| | Singhbhum Hills | 124 | 66 | 53.2 | 114 | 7 | 6.1 | 347 | 14 | 1.0 |
| | Vizaga patam | 94 | 55 | 58.5 | 779 | 71 | 9.1 | — | — | — |

No. + = number positive

M. + = number positive for man

A. I. = anthropophilous index

According to this table *A. varuna* behaves similarly to *A. fluviatilis* and *A. minimus* in the Jeypore Hills and exhibits marked anthropophilism, irrespective of the source from which it is collected, thus confirming that Senior White (1937-1938) was justified in combining the three species together into one group. On the other hand in Singhbhum Hills whereas *fluviatilis* and *minimus* collected from houses and outdoor shelters are anthropophilous and those from cowsheds appear to be mainly zoophilous, *varuna* collected from houses alone shows anthropophilism while *varuna* collected from cowsheds and outdoor shelters is markedly zoophilous the latter much more so than the former. The situation in the Vizaga patam area is different altogether. The anthropophilous index of

varuna from houses and cowsheds is similar to that of the Singhbhum Hills (there is no outdoor resting *varuna* in Vizagapatam) and *prima facie* conditions in the two areas appear to be identical. It has therefore to be emphasised that at Vizagapatam *varuna* feeds on man only when it is forced to do so on the feeding journey and, in any case dissections show that but for a very few in the human baited hut infections are entirely absent either in house or cowshed collections. This will, however, be discussed in more detail in a subsequent section. The available evidence shows beyond doubt that, in this area *varuna* is a predominantly cattle loving species.

There are thus significant variations in the food preferences of *A. varuna* not only in different areas but also according to the resting places in the same area.

Gonotrophic cycle — Senior White *et al* (1945) observed that, in the warm humid months of July and August *varuna* completes the gonotrophic cycle in 48 hours like *A. minimus* in Assam (Muirhead Thomson, 1941). There are no records of observations in other months and also whether as in the case of *fluviatilis* and *minimus* there is any time lag between completion of ovarian development and oviposition. However Senior White *et al* (1945) produced evidence showing that in *A. varuna* too digestion and ovarian development do not always proceed simultaneously. Table III shows the condition of the ovaries at the time of dissection which was made after the last blood meal was completely digested.

TABLE III

Ovarian condition of A. varuna at the time of dissection

| Where collected | Number dissected | Ovaries per cent | | |
|------------------|------------------|------------------|------------|----------|
| | | (I) | (II)—(III) | (IV)—(V) |
| Sprayed houses | 66 | 2 | 36 | 62 |
| Unsprayed houses | 90 | 1 | 31 | 68 |
| Outdoor shelters | 2188 | 8 | 48 | 44 |

About one third of the number are in early ovarian stages, which indicates that repeated feeding may sometimes be necessary for *A. varuna* to mature a single batch of eggs, denoting a condition described by Venkat Rao (1947) as gonotrophic discordance. Careful inspection was always made of the damp cotton wool at the bottom of the Barraud box but no oviposition in transit was ever revealed and it cannot, therefore, be stated as suggested by Jaswant Singh and Mohan (1951) that gonotrophic discordance is not to be presumed in such cases.

Swarming—There is no record of swarming observations in respective *varuna* but such observations are essential, in view of the hypothesis put forward, of which mention will again be made later that far from being one species *varuna* stands for more than one distinct species or at least variety of biological race.

Flight range—Venkat Rao and Philip (1947) observed the breeding of *varuna* up to about half a-mile from human habitations and presumed this to be its flight range.

Hibernation—There is no information on this point as far as the author is aware.

Longevity—No direct evidence regarding longevity of this mosquito is available. However as *fluviatilis* and *minimus* are shown to survive a period of twelve days in fair numbers and as *varuna* shows equally high infection rates as the former the longevity of the latter should be much the same but this is at best presumptive evidence.

RELATION TO MALARIA

In the Bengal area, infections were found in *varuna* by Iyengar (1942) in the Hooghly District and 24 Parganas and in the Howrah District by Roy (1939). It was therefore considered that *varuna* was an important vector, responsible for much of the endemicity in Bengal. Subsequent detailed investigations made by Iyengar (1942) however revealed a different picture. Malaria in deltaic Bengal was shown to be due to *A. philippinensis* which was the main if not the only, vector with a total infection rate of 15.5 per cent and a sporozoite rate of 12.7 per cent whereas the total infection rate of *varuna* was only 0.7 per cent and the sporozoite rate nil. Iyengar (1942)

therefore, concluded that, though *varuna* might be a potential vector and had been found infected in some places, it did not appear to play any important part in the deltaic area in determining malarial endemicity

As has already been stated *A. varuna* exists on the Orissa Coastal Plain and around the Chilka Lake but is somewhat of a rarity there at least as an adult. Senior White *et al* (1943) dissected 36 specimens in the former area but found no infections. Senior White and Adhikari (1939) dissected three specimens from the Chilka Lake area with negative results. Covell and Singh (1942) confirmed that *varuna* was encountered in this area only on a very few occasions and was not found infected at any time.

Further south in the Vizagapatam area *A. varuna* is present in very large numbers. Senior White and Venkat Rao's (1943) dissections from this area are shown in Table IV.

TABLE IV

Dissections of A. varuna in the Vizagapatam area

| Where collected | Number dissected | G+ | GI+ | I R | S R | |
|----------------------|------------------|----|-----|------|------|-------------|
| *Hut and habitations | 762 | — | 2 | 0.26 | 0.26 | *Bait traps |
| *Cowsheds | 10,567 | — | 1 | 0.01 | 0.01 | |
| Total | 11,329 | — | 3 | 0.02 | 0.02 | |

G+ = gut infected

I R = total infection rate per cent

GI+ = gland infected

S R = sporozoite per cent

It is evident that with such an exceedingly low infection index *varuna* cannot be classed as a vector of even secondary importance in this area.

On the other hand there is indisputable evidence of the strong vectorial capacity of *A. varuna* in the *Jeyapore Hills*, as the dissections listed in Table V show.

TABLE V

Dissection of A. varuna in Jeypore Hills
(Senior White, 1937-1938)

| Year | Number dissected | G+ | GI+ | I R | S R |
|---------|------------------|----|-----|------|-----|
| 1935/36 | 317 | 26 | 15 | 12.3 | 4.7 |
| 1936/37 | 189 | 8 | 2 | 5.3 | 1.1 |
| Total | 506 | 24 | 17 | 10.0 | 3.3 |

G+ = gut infected

GI = gland infected

I R = Total infection rate per cent.

S R = Sporozoite rate per cent

As already stated, Singhbhum Hills present a somewhat different picture. The infections encountered in that area are listed in Table VI.

TABLE VI

Dissections of A. varuna in Singhbhum Hills

| Authors | Where collected | Number dissected | G+ | GI+ | I R | S R |
|--|------------------|------------------|----|-----|-----|-----|
| Senior White and Das (1938) | Houses | 189 | 8 | 2 | 5.2 | 1.1 |
| Senior White and Appal Narayana (1940) | Human bait | 153 | 8 | 3 | 7.2 | 2.1 |
| Senior White et al (1945) | Outdoor shelters | 2188 | 3 | — | 0.1 | — |

G+ = gut infected

GI+ = glands infected

I R = Total infection rate per cent

S R = Sporozoite rate per cent

The corresponding sporozoite rates for *fluviatilis* and *minusus* are —

| | <i>Fluviatilis</i> | <i>Minusus</i> |
|------------------|--------------------|----------------|
| Houses | 1.8 | 3.9 |
| Human baited | 1.2 | 5.6 |
| Outdoor shelters | — | 15.4 |

Undoubtedly, *A. varuna* resting in houses of this area is as dangerous as the other two species of the group, whereas that resting in outdoor shelters (and possibly cowsheds too) is practically harmless.

therefore, concluded that though *varuna* might be a potential vector and had been found infected in some places, it did not appear to play any important part in the deltaic area in determining malarial endemicity

As has already been stated *A. varuna* exists on the Orissa Coastal Plain and around the Chilka Lake but is somewhat of a rarity there at least as an adult. Senior White *et al* (1943) dissected 36 specimens in the former area but found no infections. Senior White and Adhikari (1930) dissected three specimens from the Chilka Lake area with negative results. Covell and Singh (1942) confirmed that *varuna* was encountered in this area only on a very few occasions and was not found infected at any time.

Further south in the Vizagapatam area *A. varuna* is present in very large numbers. Senior White and Venkat Rao's (1943) dissections from this area are shown in Table IV.

TABLE IV

Dissections of A. varuna in the Vizagapatam area

| Where collected | Number dissected | G+ | GI+ | I R | S R | |
|--------------------|------------------|----|-----|------|------|---------------|
| *Human habitations | 762 | — | 2 | 0.26 | 0.26 | *Baiting huts |
| *Cowsheds | 10,567 | — | 1 | 0.01 | 0.01 | |
| Total | 11,329 | — | 3 | 0.02 | 0.02 | |

G+ = gut infected

I R = total infection rate per cent

GI+ = gland infected

S R = sporozoite per cent

It is evident that with such an exceedingly low infection index *varuna* cannot be classed as a vector of even secondary importance in this area.

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I R = Total infection rate per cent.

GI = gland infected

S R = Sporozoite rate per cent

As already stated Singhbhum Hills present a somewhat different picture. The infections encountered in that area are listed in Table VI.

TABLE VI

Dissections of A. varuna in Singhbhum Hills

| Authors | Where collected | Number dissected | G+ | GI+ | I R | S R |
|--|------------------|------------------|----|-----|-----|-----|
| Sen or White and Das (1938) | Houses | 189 | 8 | 2 | 5.3 | 1.1 |
| Sen or White and Appal Narayana (1942) | Human bait | 123 | 8 | 3 | 7.3 | 2.1 |
| Sen or White et al (1945) | Outdoor shelters | 2188 | 3 | — | 0.1 | — |

G+ = gut infected

GI+ = glands infected

I R = Total infection rate per cent

S R = Sporozoite rate per cent

The corresponding sporozoite rates for *fluviatilis* and *minimus* are —

| | <i>Fluviatilis</i> | <i>Minimus</i> |
|------------------|--------------------|----------------|
| Houses | 1.8 | 3.9 |
| Human baited | 1.2 | 5.6 |
| Outdoor shelters | — | 15.4 |

Undoubtedly *A. varuna* resting in houses of this area is as dangerous as the other two species of the group whereas that resting in outdoor shelters (and possibly cowsheds too) = practically harmless.

In the Hazaribagh Ranges which adjoins the Singhbhum Hills *A. minimus* is an extreme rarity. *A. varuna* is present in somewhat large numbers but is not as common as in the Jepore and Singhbhum Hills. In the Hazaribagh Ranges altogether 131 *varuna* were dissected and three gut and two gland infections were found, the total infection and sporozoite rates being 3.8 and 1.5 per cent respectively. During the same period 2167 *fluviatilis* were dissected showing a total infection rate of 3.2 per cent and a sporozoite rate of 1.4 per cent. In spite of finding high infection rates in *varuna* Senior White and Venkat Rao (1943) concluded that in this area the principal vectors was *fluviatilis* and that *varuna* was too rare to play any considerable part in transmission.

A. minimus is extremely rare in the Eastern Satpura Ranges also and *A. fluviatilis* and *A. varuna* dominate the field. Senior White and Adhikari (1940) dissected 326 *varuna* and found a total infection rate of 7.7 per cent and a sporozoite rate of 3.7 per cent; the corresponding rates for *fluviatilis* being 7.2 and 2.8 respectively. The conclusion of these authors that *fluviatilis* and *varuna* are the principal vectors is thus justified. In Travancore Mathew (1939) dissected 429 specimens with an oocyst rate of 2.3 and a sporozoite rate of 1.6 per cent; considered it a dangerous carrier.

Outside India *varuna* is not shown to be a vector either in Burma or in Ceylon. Fox (1950) says that in Burma *varuna* is unlikely to play any part in malaria transmission. Adults of *varuna* are so rare in houses and cowsheds in Ceylon that, in spite of its prolific breeding, it is not thought to be a vector in that country (Rajendram and Jayewickreme 1951). The vectorial status of *varuna* is thus shown to vary widely from one area to another.

POSSIBLE EXISTENCE OF VARIETIES OR BIOLOGICAL RACES

When they found that *A. varuna* was a negligible factor in the epidemiology of malaria around Vizagapatam Senior White and Venkat Rao (1943) held out the hypothesis that the *varuna* of Vizagapatam might be specifically distinct from that of the Jeypore Hills. And when a cattle-loving form was discovered subsequently in Singhbhum Hills along with a form of high vectorial potency Senior White *et al.* (1945) observed that there were such extreme differences in the behaviour of this species as to furnish further evidence in favour of the hypothesis that *varuna* covers more than

one species or biological race The existence of biological races in certain species has been recognized for some time and it has also been suggested that, within a particular species complex, some races might be vectors and others not For instance, while *A. culicifacies* is the sole vector of malaria in the Punjab and in some areas of South India, it is of no importance whatever in large parts of the country including East Central India, Assam, Bengal and Orissa No variations in the morphological characters of *culicifacies* from various areas have, however, been detected, which led to the conclusion by Russel and Ramachandra Rao (1942) that the ability of this species to transmit malaria depended mainly on its numbers On the other hand, Afridi *et al* (1939) produced evidence that the intensity of human feeding which must ultimately influence transmission, varied according to the relative proportion of man and animals particularly cattle The above observations were at variance with those made by Senior White and Venkat Rao (1943) at Vizagapatam where with adequate densities but with a higher anthropophilous index than in Delhi and South India, *culicifacies* did not play any part in transmission at all One is thus compelled, as it were, to revert to the question of biological races, for an explanation of these contradictions The references made by Huxley (1942) to the existence of biological races are given the force of axioms, he is so certain about them He goes on to observe that much of speciation is concerned with invisible physiological characters rather than morphological differences, that groups may remain perfectly distinct though morphologically indistinguishable, that differences in ecological preferences may isolate groups as effectively as geographical or spatial barriers and that, certainly in most phyla and probably in all, there exist groups of individuals which are undoubtedly distinct in every sense except the accepted morphological one

When we find every conceivable difference in the ecology and behaviour of *varuna* in different areas or even within the same areas as indicated in the foregoing account, there is nothing improbable in the hypothesis that there are various species or races involved and it would be of interest, not only in an academic sense but also from the point of view of practical malaria control measures to carry out an intensive study of the phenomenon There is already some evidence which serves as a clear pointer in this direction The eggs of this species from the Jeypore Hills and Vizagapatam were

definitely shorter (394 op) than the former (415 su) but, when the enquiry was extended to other areas of *varuna* prevalence, further differences appeared, which required *de novo* study of the whole matter, (Senior White and Venkat Rao 1943) Owing to preoccupation with other pressing work, these authors were unable to continue the study but it is hoped that other interested workers will do so hereafter

CONTROL

Specific control measures against *varuna* are not probably required in any area. Along the east coast of India from Assam to Vizagapatam (and perhaps down to Madras or further south) this species is not of any practical importance. In areas of its undoubted importance such as Jeypore and Singhbhum Hills and Eastern Satpura Ranges it is always associated with *fluviatilis* and *minimus* and, since the feeding and resting habits of at least the house haunting adults of the three species are identical whatever measures are taken against these two species are *ipso facto* effective against *varuna* as well. As these three species exist largely in rural areas and breed in the numerous seepages, streams and 'seepage rice fields', anti-larval measures may be ruled out altogether there owing to their cost. Senior White and Venkat Rao (1944) have shown that pyrethrum spraying against *varuna* and the other members of the group is not effective except when the costly method of daily spraying is applied. On the other hand, DDT spraying has been shown to be an economical and effective method of controlling *varuna* (Senior White and Ghosh, 1946). They sprayed inside of houses with a five per cent DDT kerosine solution at the rate of one quart of the solution per 600 to 1,000 square feet (average dosage about 70 mg per square foot) and found it effective from two to six months, the residual effect being prolonged progressively with each successive spray round. Probably annual spraying at a dosage of 200 mg per square foot, using DDT water dispersible powder instead of solutions and emulsions, would be the method of choice, owing to its economy and efficiency.

REFERENCES

- Afridi M K, Jaswant Singh and (1939) : *J Mal Inst Ind*, 2, p 219
 Harwant Singh
 Christophers S R (1933) : *Fauna of British India*, Vol IV
 Taylor & Francis, London

| | | |
|---|--------|---|
| Chr istophers S R and Pur I M | (931) | <i>Rec Mal Surv Ind</i> 2 p 463 |
| Covell ■ and Singh P | (1942) | <i>J Mal Inst Ind</i> 4 p 457 |
| Fox D G R | (1950) | <i>The Anopheles Mosquitoes of Burma</i> Thesis Photostat copy |
| Hux ey J | (1942) | <i>Evolution the modern synthesis</i> George Allen and Unwin Ltd London |
| Iyengar M O T | (1924) | <i>Ind J Med Res</i> 12 p 23 |
| Idem | (1942) | <i>J Mal Inst Ind</i> 4 p 415 |
| Jaswant Singh and Mohan ■ N | (1951) | <i>Ind J Mal</i> 5 p 513 |
| Mathew M I | (1939) | <i>J Mal Inst Ind</i> 2 p 101 |
| Murhead Thomson R C | (1941) | <i>Ibid</i> 5 p 217 |
| Puri I M | (1931) | <i>Ind Med Res Mem</i> 21 |
| Randram S and Jayawickreme S H | (1951) | <i>Ind J Mal</i> 5 p 1 |
| Roy D N | (1938) | <i>J Mal Inst Ind</i> 1 p 269 |
| Idem | (1939) | <i>Ibid</i> , 2 p 239 |
| Russel P F and Ramachandra Rao T | (1940) | <i>Ibid</i> 3 p 153 |
| Idem | (942) | <i>Am J Trop Med</i> 22 p 57 |
| Sen or Whit R | (1937) | <i>Rec Mal Surv Ind</i> 7 p 47 |
| Idem | (1938) | <i>J Mal Inst Ind</i> 1 p 29 |
| Idem | (1941) | <i>Ibid</i> 4 p 57 |
| Idem | (1946) | <i>Ibid</i> 6 p 437 |
| Idem | (1947) | <i>Ind J Mal</i> 1 p 11 |
| Sen or White R and Adhikari A K | (1939) | <i>J Mal Inst Ind</i> 2 p 395 |
| Idem | (1940) | <i>Ibid</i> 3 p 383 |
| Sen or White ■ and Appalaraju yan P | (1940) | <i>Ibid</i> 3 p 413 |
| Sen or White ■ and Das B K | (1938) | <i>Ibid</i> 1 p 169 |
| Senior White R, Adhikari A K, Ramkrishna V and Roy B B | (1943) | <i>Ibid</i> 5, p 159 |
| Senior White R and Ghosh A R | (1946) | <i>Ibid</i> 6 p 489 |
| Sen or White R, Ghosh A R and Venkat Rao V | (1945) | <i>Ibid</i> 6 p 129 |
| Sen or White ■ and Venkat Rao V | (1943) | <i>Ibid</i> , 5 p 187 |
| Idem | (1944) | <i>Ibid Med Gaz</i> 79 p 364 |
| Venkat Rao, V | (1947) | <i>Ibid J Mal</i> 1 p 43 |
| Venkat Rao V and Philip M I | (1947) | <i>Ibid</i> 1 p 37 |
| Venkat Rao V and Ramakrishna V | (1940) | <i>J Mal Inst Ind</i> 3 p 509 |
| Vasanthan D K, Ramachandra Rao T and Rama Rao T S | (1944) | <i>Ibid</i> , 5 p 449 |

BREEDING PLACES

Larvæ occur in clear slow-running water, in foot hill and other streams, in irrigation channels, along grassy edges of flowing water, seepages and other shallow water collections. It is often found breeding in rice fields and occasionally in margins of swamps and tanks. In South China larvæ have been taken from pools, ponds, swamps terraced rice fields (Chang 1940), and in seepage water and fallow rice fields (Chow, 1949). In Arakan, it was found breeding particularly in the parts thickly overgrown with vegetation often where standing water was not visible till a pool gathered around collectors feet (Macan 1950). Working in Tonkin Tojmanoff (1932) mentioned breeding of this species in wooded hilly area with swampy valley, and mountainous regions with enough seepage water. Jackson (1951) collected larvæ from water in the stubbles and observed that flooded fallow rice fields and fields with second crops ripening revealed larvæ of this species in hilly locales of Hongkong.

The type form and its variety have similar larval habits (Boyd 1949). In Jeypore and Singhbhum hills *A. jeyporensis* was found to prefer breeding in seepage fields over jungle nala and non-seepage fields (Seniorwhite 1946). The rice field breeding of the type form revealed that 75 per cent prefer fallow fields, 22 per cent broadcast and 3 per cent transplanted fields (Seniorwhite, loc cit). Like other members of the stream breeding group this species is found in water with temperature ranging from 23° to 33°C with an optimum at 28°C (Seniorwhite, loc cit).

BIONOMICS

Seasonal Prevalence — *A. jeyporensis* and its variety *candidiensis* abound in relatively dry period of the year. Macan (1950) noted high density during April May in Arakan region of Burma where the rainfall occurs from June to October. However, the same author (1948) found it in high numbers during the rains in Kabaw and Kale valleys of Burma. Working in Hongkong, Jackson (1951) found little breeding during May to October (rainy season) and observed a high density during October and November. In Jeypore Hills the type form is reported to be abundant during November to March while it disappears from August to September (rainy season). Singh and Jacob (1944) did not find the type form in

North Kanara (Bombay) during the monsoon. They believe that this was due to continuous flushing of larvæ in the streams.

Resting Places The type form is a proven indoor rester. Various workers have observed that it prefers cattle-sheds and stables to human or mixed dwellings (Russel and Jacob, 1942, Singh and Jacob 1944, Seniorwhite *et al*, 1945). The ratio of daily cow-shed catches to daily house catches is 1378 : 1, (Seniorwhite *et al*, (1945). However the reports about variety *candidiensis* are conflicting. As already mentioned, this may partly be due to the fact that the variety and the type form were not always recorded separately by workers outside India. Macan (1950) and Watson (quoted by Macan, *loc cit*, and Postiglione and Venkat Rao 1956) found this form in considerable number near man at night. These workers did not find them in houses during day and near cattle during night. Feegrade (quoted by Postiglione and Venkat Rao, 1956) found good numbers in houses and cow-sheds in Bhamo area of Burma. Macan (1948) collected 63 mosquitoes indoors of which only two to three per cent were with old blood. He concluded that very few specimens spent the day in their feeding places. The same worker in an experiment with human baited tents observed that all specimens tended to rest for an appreciable period near the source of food before making an attempt to feed. Seniorwhite *et al* (1945) also observed that the type form moves away from the feeding site for the second half of digestion being in the house for one daylight period only in each cycle.

Seniorwhite and Ghosh (1946) noted the following preferential resting spots inside dwellings for the type form in Jeypore Hills —

(Figures in Per Cent)

| Wall and door | Thatch roof | Floor | Furniture | Clothing and hanging objects | Firewood |
|------------------|----------------|-------|-----------|---------------------------------|----------|
| 42.5 | 34.0 | 5.5 | 12.0 | 4.5 | 1.5 |

According to Jackson (1951) variety *candidiensis* prefers dark corners and hanging clothes for resting indoors.

Feeding Time —Macan (1950) observed that this species enters 'bashes' between 22.00 hours and midnight, mostly fed between 01.30 and 03.30 hours and disappeared. In rooms without smoke, the

whole course of events took place earlier and some freshly fed mosquitoes were found between 21 00 and 21 30 hours. There was no entry at dawn. In night catches Nursing *et al*, (1934) collected more specimens (type form) between 4 hours to 11 hours than between 21 00 hours and midnight (54.0 and 46.0 per cent respectively).

Gonotrophic Cycle —Seniorwhite *et al* (1945) mention the gonotrophic cycle to be seventy-two hours for the type form. However, it is likely that this may vary with seasonal temperature variations as is the case with other species.

Anthropophilic Index —Seniorwhite *et al* (1945) mention that the type form has a high anthropophilic index in presence of human blood. The variety *candidiensis*, also is regarded as having a high anthropophilic index. Macan (1950) collected more mosquitoes using human baits than with cattle baits. Jackson (1951) got the following results from precipitin test conducted on the variety in Hongkong —

| Number examined | Number positive | Antisera | | | | | |
|--------------------|--------------------|----------|--------|-----|-----|-------|-------|
| | | Man | Cattle | Pig | Dog | Horse | Mixed |
| 214 | 188 | 103 | 72 | 2 | 1 | 8 | 2 |

However at one station (Woo Li Hop), where cattle and animals lived side by side their owners the precipitin test revealed equal numbers reacting to human and animal sera. Toumanoff (1936) stated that in Indo China when caught in houses it always contained human blood and occasionally did so even when captured in stables or cattle sheds. He classed it as highly anthropophilic with great animal deviation (as also proven by Jackson *loc cit*). Raynal and Gaschen (1935) found that seventy two per cent of 370 caught in dwellings in Indo China had fed on man.

Flight Range —According to Jackson (1935) the flight range of *candidiensis* in Hongkong exceeds half a mile. Seniorwhite *et al* (1945) experimentally showed that the type form in Jeypore Hills goes beyond 1,400 ft for ovipositing.

Longevity —There is a very high percentage of survival for over twelve days in the cold weather in the case of *A. jeyporensis* (Seniorwhite *et al*, 1945). No record of the longevity for varietal form is available.

TABLE I

Incidence of *Plasmodium* SPP. in Wild Caught *A. jeyporiensis* (type form) and var *Candidiensis*

| Locality | Reference | Number dissected G/Gi | Number positive G/Gi | Per cent positive G/Gi | Total infection | Per cent infection | Remarks |
|--|--------------------|--------------------------|-------------------------|---------------------------|-----------------|--------------------|---|
| Burma | | | | | | | |
| Arakan-East Pakistan (Apr., 1944) | Macan, 1950 | -/126 | -/2 | /166 | 2 | 16 | |
| Kabaw and Kale valleys (May, Sep., Oct., Dec (1944) | Macan 1948 | -/164 | -/x | /x | 0 | 00 | |
| China | | | | | | | |
| Amoy Is (Fukien) (July Aug., 1931) | Feng, 1932 | 30/27 | 1/x | [*] 33/x | 1 | [*] 33 | With only young pigmented oocysts (Data from authors' table) (Covell, 1944) |
| Kwangsai | Feng, 1936 | 56 | 2/x | [*] 36/x | 2 | [*] 36 | (Covell 1944) |
| Yunnan | Ling et al 1936 | 53 | x/1 | [*] x/19 | 1 | [*] 19 | (Covell 1944) |
| Mongshih, Yunnan (July-Oct., 1939) | Robertson, 1941 | 108 | 4/5 | [*] 37/46 | 6 | 555 | Six heavy infections |
| Hongkong, 1933 34 | Jackson 1951 | 28706 | 1085/616 | [*] 48/21 | 1701 | [*] 59 | |
| | | 277 | -/- | | [*] 14 | 505 | |

(Continued)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|--------------------------|---------|-----|-------|---|-----|--|
| India: | | | | | | | |
| Jeypore Hills (Mar - Nov, 1912) | Perry, 1914 | 61/402 | x/x | x/x | 0 | 00 | |
| Bengal | | | | | | | |
| Gachar (Assam) | Fry, 1914 | 20 | x/x | x/x | 0 | 00 | |
| (Apr, Dec, 1927) | Strickland, 1929 | 125 | x/x | x/x | 0 | 00 | |
| Cachar, 1927-1929 | Ramsay, 1930 | 888 | x/x | x/x | 0 | 00 | |
| Kufasekharam, Travancore (Feb 1932-Sept 1933) | Jyengar, 1934 | 3833 | 3/x | 008/x | 3 | 008 | 98 oocysts in three infections One had well differentiated sporozoites Oocysts appeared mostly of <i>P. falciparum</i> and a few were <i>P. malariae</i> |
| Mysore (1932-1933) | Nursing et al. 1934 | 671/667 | 2/x | 03/x | 2 | 03 | Total dissections 674 |
| Assam (1933-1934) | Ramsay et al 1936 | 2020 | 1/x | 005/x | 1 | 005 | |
| Jeypore Hills (1935-1936) | Seniorwhite, 1937 | 318 | 4/x | 13/x | 4 | 13 | Specimens showing infection were collected from human dwellings |
| Singbhum Hill (1935-1938) | Seniorwhite and Das 1938 | 81 | x/x | x/x | 0 | 00 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|--------------------------------------|------------|------------|------------|--------|----------|----------------------------------|
| Kulasekaram, Perumpazhuthoor (Aug. 1937-Aug. 1938) | Mathew 1939 | 49 3559 | x/x x/x | x/x x/x | 0 0 | 00 00 | |
| Chedleth, Wynaad (1938-1939) | Covel and Harbhagwan, 1939 | 2494 | v/v | x/x | 0 | 00 | |
| Singhbhum Hills (1939-1940) | Seniorwhite and Narayana, 1940 | 89 | x/x | x/x | 0 | 00 | |
| Nilgiris (1940-1941) | Russell and Jacob, 1942 | 377 | x/x | x/x | 0 0 | 00 00 | |
| Ketti Oct. 1941 Hazaribagh ranges | -do- Seniorwhite, 1943 | 1 348 | x/x x/x | x/x x/x | 0 | 30 | |
| Jeypore Hills (Mar., 1942-Feb., 1943) | Seniorwhite et al. 1945 | 135 | 4/x | 30/x | 4 | 00 | |
| North Kanara (May 1942-May 1943) | Singh and Jacob, 1944 | 1875 | x/x | v/v | 0 | 00 | |
| Udaipur, Madhya Pradesh Aug.-Nov., 1942 | Roy and Bis- was, 1942 | -/32 | -/x | /x | 0 | 00 | 31 caught in human dwellings. |
| Jeypore Hills (Nov., 1944-Apr., 1945) | Seniorwhite, 1945 | 248 | 1/x | * 04/x | 1 | * 04 | |

(Continued)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------------|--------------------------|------|-------|-----------|----|------|---------------------------------|
| Indo China | | | | | | | |
| Tonkin (Jan 1931-1932) | Toumanoff, 1932 | 133 | 3/x | 2 25/x | 3 | 2 15 | Oocysts filled with sporozoites |
| Red River Delta (1931-1935) | Gaschen and Marneff 1916 | 3419 | 22/18 | 0 64/0 52 | 34 | 0 99 | |
| do- | Raynal and Gaschen 1935 | 2878 | | | 27 | 0 94 | (Horsfall, 1955) |
| Annam | Toumanoff, 1936 | 424 | 3/x | 0 7/x | 3 | 0 7 | (Covell 1944) |
| South Indo China | do- | 58 | x/1 | x/1 72 | 1 | 1 72 | (Covell 1944) |
| Tonkin | -do- | 826 | 4/2 | 0 48 0 24 | 6 | 0 7 | (Covell, 1944) |

* Calculated figures
G for Gut G1 for Gland

RELATION TO MALARIA

The results of dissections of *A. jeyporensis* and its variety *candidiensis*; recorded so far, have been set in Table I. No infective mosquito has been found amongst wild-caught specimens from present day India. Oocysts have been recorded in specimens from Jeypore Hills (Seniorwhite 1937 and 1945, Seniorwhite *et al*, 1945), in Assam (Ramsay *et al*, 1936), in Mysore (Nursing *et al*, 1934) and in Travancore (Iyengar, 1934a). Contrary to reference available in the literature about var. *candidiensis* being a vector, this evidence leads to the conclusion that this varietal complex is not involved in malaria transmission in this country. However from very early times (Stephens and Christophers, 1902, Perry, 1914), due to its presence in large numbers in areas of high malaria endemicity this species has been considered a potential vector in areas of its distribution in India. The oocysts in case of Iyengar's dissections are reported to have contained mature sporozoites. Therefore, it may be just dame luck that has prevented incrimination of this species (type as well as variety) as a vector. Future dissections may yet reveal an infective specimen in India.

Outside India, the varietal form (although not always designated so) is considered a premonsoon vector of importance on Burma-East Pakistan border (Macan, 1950), Hongkong (Jackson 1935, 1951), and Indo-China (Toumanoff 1932-1936), and of secondary importance in South China (Chow 1949).

All these areas are hyperendemic, and *A. minimus* is the important associate vector.

CONTROL

No specific data is available on the control of *A. jeyporensis* var *candidiensis* by the use of insecticides (Singh *et al* 1954, Pal and Sharma 1955). Seniorwhite and Ghosh (1946) recorded upto ten fold reduction in density of the type form by spraying one quart of five per cent solution of DDT per 1000 sq ft. Jackson (1951) eliminated breeding of the varietal form by preventing flooding of rice fields. Covell and Harbhagwan (1939) prevented breeding of the type form by packing of rice field drains.

It seems that proper care of irrigation drains and rice field drainage and the use of residual insecticides would check malaria transmission by this species.

REFERENCES*

- Boyd, Mark F (1949) *Malariaology*, 1, p 490, 678 2, p 815
W H Saunders Co., Philadelphia and London
- Change T L, (1939) Mosquitoes of Hunan Province
Ch na Med J, 56, ■ 52 62
- Idem* (1940) The anopheline mosquitoes of Yunnan
Ibid, 58, ■ 218 233
- Chow, C Y (1949) The identification and distribution of Chinese anopheline mosquitoes
J Nat Mal Soc Columbia 8 p 121 131
- Christophers, S ■ (1933) *The Fauna of British India* 4, ■ 220-225
- Covell, G (1927a) The distribution of anopheline mosquitoes in India and Ceylon
Ind Med, Res Mem 5, p 1 82
- Idem* (1927b) A critical review of the data recorded regarding the transmission of malaria by the different species of *Anopheles* with notes on distribution habits and breeding places
Ibid 7, p 1 17
- Idem* (1944) Notes on the distribution breeding places adult habits and relation to malaria of the anopheline mosquitoes of India and the Far East
J Mal Inst Ind 5 p 399 434
- Covell ■ and Harbhag (1939) Malaria in the Wynad, South India
wan J *Ibid* 3, p 341 376
- Feng L. C. (1932) Investigations of malaria and its transmission in Amoy, Fukien Province, China.
J Trop Med (Hyg) 35 ■ 198 202 214 221
- Idem* (1935) The present status of the knowledge of the mosquitoes of China and their relation to human disease
China Med J, 49 p 1183 1208
- Idem* (1936) Malaria and its transmission in Kwangsi China
Ibid, 50, p, 1799 1814
- Idem* (1937) The anopheline mosquitoes and the epidemiology of malaria in China
Ibid, 51, ■ 1005 1020
- Idem* (1938) A critical review of literature regarding the records of mosquitoes in China
Peking Nat Hist Bull 12, ■ 169 181
- Fry, A B (1914) Second report on malaria in Bengal
Bengal Sect., Book Depot Calcutta
- Gaschen H (1936) Natural infection of anophelines in Tonkin
Bull Soc Path Exot 29, p 1093 1095
- Gaschen, H & Marneff H (1936) Infection in wild caught *A. byrcanus* var *sinensis* in the Red River Delta
loc cit, p 970-975
- Horsfall, W R (1955) Mosquitoes their bionomics and relation to disease p 239 241
The Ronald Press Co N Y

* References include literature consulted in preparing this review

VIII *Anopheles jeyporensis* var *candidiensis* Koidzumī 1924 97

- | | | |
|---------------------------------|---------|--|
| Engar M O T | (1926) | The anopheline fauna of a swamp in Bangalore <i>Ind J Med Res</i> 13, p 69-702 |
| <i>Idem</i> | (1934a) | Anophelines found naturally infected with malaria parasites in Travancore <i>Rec Afri Surv Ind</i> 4, p 61-63 |
| <i>Idem</i> | (1934b) | Anophelines infected with malaria parasites a further note <i>loc cit</i> p 371-372 |
| <i>Idem</i> | (1936) | Report of malaria and filariasis surveys and other investigations 1931-1934 Government Press, Trivandrum |
| Jackson R B | (1935) | The anophelines of the colony of Hong Kong <i>Trans Nth Cong Far East Assn Trop Med</i> 2 p 27-36 |
| <i>Idem</i> | (1936) | Investigations into the habits and pathogenecity of the anophelines met with in two localities in Hongkong during 1931-1935 <i>China Med J</i> , 50 p 1098-1113 |
| <i>Idem</i> | (1951) | A review of investigations of the habits and pathogenecities of the common anophelines of Hongkong <i>Trans Roy Soc Trop Med Hyg</i> 45 ■ 91-101 |
| Long L C Lin, K B, and Yao Y T | (1936) | Studies on the so called Changchi Part II Changchi in Yunnan <i>China Med J</i> 50, p 1815-1828 |
| Mason T T | (1948) | Mosquitoes and malaria in the Kabaw and Kale valleys, Burma <i>Bull Ent Res</i> 39 p 237-268 |
| <i>Idem</i> | (1950) | Malaria Survey of the Arakan region of Bengal and Burma <i>Parasitology</i> 40, p 290-297 |
| Mathew M I | (1939) | Anopheline transmitters of malaria in South Travancore <i>J Mal Inst Ind</i> 2, p 101-104 |
| Nurung D, Rao B A and Sweet W C | (1934) | Notes on malaria in Mysore State, Part VII The anopheline transmitters of malaria <i>Rec Afri Surv Ind</i> 4, p 243-251 |
| Pal, R. and Sharma M I D | (1955) | Malaria control by the use of insecticides <i>Ind J Mal</i> 9 p 385-401 |
| Perry, E L | (1914) | Endemic malaria of the Jeypore Hill tracts of the Madras Presidency <i>Ind J Med Res</i> 2, p 456-491 |
| Postiglione M, and Venkat Rao V | (1956) | Malaria in Burma <i>Ind J Mal</i> 10, p 273-398 |
| Puri I M | (1955) | The distribution of anopheline mosquitoes in India <i>Health Bull No 17, Manager Publications, Government of India, Delhi</i> |
| Ramsay G C | (1930) | Some findings and observations in an anopheline malaria infectivity survey carried out in the Cachar district of Assam <i>Ind J Med Res</i> , 18, p 533-552 |

- Ramsay, G E Chandra, and Lamprell, B A (1936) *The results of precipitation tests applied to Anopheles in N Indo-China*
Bull Soc Path Exot 28, p 937-943
- Raynal, J, and Gaschen, H (1935) *Malaria in W Yunnan with reference to the China Burma Highway*
Chinese Med J, 57, p 57-73
- Idem* (1934) *A malaria survey on the China Burma Highway*
Trans Roy Soc Trop Med Hyg, 34, p 311-332
- Roy, D N, and Baswas, T C (1942)
- Roy, D N, and Brown, A W A (1954) *Entomology (Medical and veterinary)*
Excelsior Press Calcutta
- Russell, P F, and Jacob V P (1942) *On the epidemiology of malaria in the Nilgiris District Madras Presidency*
J Mal Inst Ind 4 p 349-392
- Russell, P F Rozeboom L E, and Stone, A (1943) *Keys to the anopheline mosquitoes of the world* The American Ent Soc Publ
Lancaster Press, Inc Philadelphia
- Seniorwhite, R (1937) *On malaria transmission in the Jeypore Hills*
Rec Mal Surv Ind 7, p 47-75
- Idem* (1943) *On malaria transmission in the Hazaribagh ranges including Ranchi plateau*
J Mal Inst Ind 5, p 207-231
- Idem* (1945) *House spraying with DDT and with pyrethrum extract compared* First results
Ibid, 6, p 83-93
- Idem* (1946a) *On the outdoor resting of some species of Oriental Anopheles*
loc cit, p 425-435
- Idem* (1946b) *Anopheline breeding in Ricefields*
loc cit p 437-468
- Idem* (1947) *On the anthropophilic indices of some Anopheles found in East Central India*
Ind J Mal, 1, p 111-122
- Seniorwhite R, and Das B K (1938) *On malaria transmission in the Singhbhum Hills*
J Mal Inst Ind 1, p 169-184
- Seniorwhite, R, and Ghosh, A R, (1946) *House spraying with DDT* Further results
Ibid, 6 p 489-508
- Seniorwhite, R, and Narayana, P A (1940) *On malaria transmission in Singhbhum Hills*
Ibid 3, p 413-425
- Seniorwhite R, Ghosh, A R, and Rao, V V (1945) *On the adult bionomy of anophelines with malaria control by*
Ibid 6 p 129-215

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- | | | |
|-------------------------------------|--------|---|
| Singh J and Jacob, V P | (1944) | Malaria investigations in North Kanara <i>Ibid</i> 5 p 267 303 |
| Singh J, Pal H and Bhatia, M L | (1954) | Control of anopheline vectors of oriental region with residual insecticides <i>Bull Nat Soc Ind Mol Atm & Dis</i> , p 31 45 |
| Stephen J W W and Christophers R | (1902) | The relation of species of <i>Anopheles</i> to malarial endemicity <i>Repts Mal Com Roy Soc Ser</i> 7, p 15 23 |
| Strickland C. | (1925) | The mosquito factor in the malaria of Tea Gardens <i>Ind Med Gaz</i> 60 p 514 525 |
| Idem | (1929) | The relative malaria infectivity of some species of anophelines in Cachar (Assam) <i>Ind J Med Res</i> 17 p 174 18 |
| Tennant C | (1932) | Preliminary note on the transmission of malaria in Tonkin in relation to the physical features of the country <i>Bull Soc Path Exot</i> 25 p 276 98, |
| Idem | (1936) | Anophelism in the Far East <i>Coll Soc Path Exot Monog</i> 4 Masson and Co, Paris |
| Young T C M and Daly, J D | (1928) | Malaria in Coorg <i>Ind J Med Res</i> , 15 p 745 99 |

IX. ANOPHELES LEUCOSPHYRUS DONITZ, 1901

BY
B S KRISHNAMURTHY
(Malaria Institute of India, Delhi)
[August 16, 1954]

A LEUCOSPHYRUS is readily distinguished by the broad white band covering the tibio-tarsal joint of the hind leg and was described as *A elegans* by James (1903) from Karwar District, Bombay State. This was later synonymised as *A leucosphyrus* Donitz 1901 by James and Stanton (1912). *A leucosphyrus* in its different forms has since been identified in the oriental region from India to Celebes and from Java to Formosa. The species complex is considered to be a group consisting of forms (Reid 1949) known by the following nomenclature —

- 1 *A leucosphyrus leucosphyrus* Donitz, 1901
- 2 *A leucosphyrus* var *elegans* James, 1903
- 3 *A leucosphyrus* var *hackeri* Edwards, 1921
- 4 *A leucosphyrus* var *balabacensis* Baisas, 1936
- 5 *A leucosphyrus* var *riparis* King and Baisas 1936
- 6 *A leucosphyrus* var *pujutensis* Colless, 1948
- 7 *A. cristatus* King and Baisas, 1936

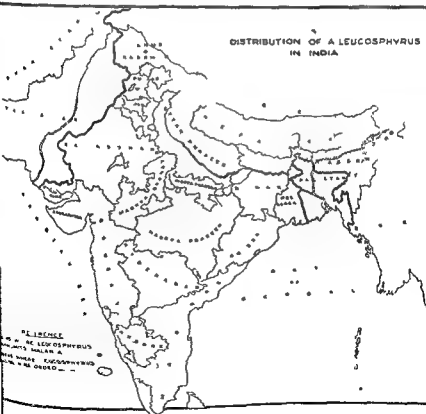
DISTRIBUTIONS

In India, it has been recorded from Assam, Andamans, Bombay, Bengal, Coorg, Konkan, Malabar, Madras (South East), Mysore, Travancore-Cochin (Map 8). Outside India, it occurs in Burma, Borneo, Ceylon, Celebes, Indo China, Java, Malaya, Sumatra, Thailand, South China and Philippines.

BREEDING HABITS

A leucosphyrus is essentially a jungle breeder. Earliest record of its breeding habits are by Cogill (1903) who found that its preferential breeding places are jungle streams or pools covered by dense shade and containing decaying leaves. A study of subsequent workers reveals that this s

breeding in a great variety of waters Christophers (1912) in Andaman found them breeding in pools besides forest streams and Covell (1927) in pools in the open and disused wells In Bengal Terai, Puri (1931) found *A. leucosphyrus* breeding in rain water in borrowpits along the side of the road, in thick forest Clarke and Choudhury (1941) in Assam reported breeding in pools made by elephant footprints in the open jungle Senior White (1926) in Ceylon found *leucosphyrus* breeding at the head of a ravine with no forest of any kind within some miles Macan (1948) recorded that one of the breeding habit was open sunlit McArthur (1947) reports *leucosphyrus* larvæ to be very shy They were easily disturbed and rapidly hid in the sediment at the bottom of either the pool or dipper as the case may be and remained submerged much longer than was the case with other species The larvæ were actually timed by him to remain submerged for five minutes or more He



Map 8.

emphasized that this feature of the larvæ remaining submerged for unusually long periods was found responsible for the delay in detection of *A. leucosphyrus* as common breeder in Borneo. McArthur (*loc cit*) and Reid (*loc cit*) recorded differences in the breeding habits of the varieties.

BIONOMICS

Adult resting places — *A. leucosphyrus* is widely believed to be a wild species inhabiting jungle under outdoor condition during day time. In spite of that, it has frequently been captured in human habitations during nights. Lalor (1912), Christophers (*loc cit*) Covell (*loc cit*) and McArthur (*loc cit*) have recorded indoor catches of *leucosphyrus* only during nights. Roper (1914) in Borneo found them present abundantly inside defective mosquito nets in coolie huts engorged with fresh blood. In Assam, Clarke and Choudhury (*loc cit*) caught them from the living rooms often inside the mosquito nets. Clarke (as quoted by Macon, 1948) suggested that the fact that they were caught only from mosquito nets indicate that the nets acted as traps. He considered that *A. leucosphyrus* mosquito engorged with blood made less strenuous effort to find a hole in the mosquito net than she did when she was outside and hungry. McArthur (*loc cit*) records that in Borneo these mosquitos rested for a short time on the walls of the houses where they fed and got away before dawn to their unknown outdoor resting places and were completely absent from the houses on examinations by conventional methods. He also noted that this mosquito had never been found resting indoors either by day or night, unlike other mosquitoes it was rarely found feeding on animals but it was found only in human bait traps after long observations lasting for days. Macon (*loc cit*) in a night catch of 128 fully fed *A. leucosphyrus* females mosquitoes noted that only one mosquito had half digested blood and the rest were engorged with fresh blood. This he correlated with the absence of *leucosphyrus* from the human dwellings during day and night catches and concluded that it did not rest indoors. McArthur (*loc cit*) stipulated that probably they rest in the jungle where they return after feeding in the early hours of the morning. Venhuis (1942) observed in East Java the adults of *leucosphyrus* resting on banks of streams. Colless (1953b) has recently reported that 80 per cent of the females rested for ten to twenty minutes on the walls inside houses before feeding and almost all rested for thirty to sixty minutes after feeding.

Feeding habits and biting time —Roper (*loc cit*) Clarke and Choudhury (*loc cit*), McArthur (*loc cit*) and Macan (*loc cit*) all recorded as having caught *A. leucosphyrus* females engorged with fresh blood from defective mosquito nets. This signifies the preferential habits of this mosquito for feeding on man. Allman (quoted by McArthur, 1951) in NW Borneo caught eleven *leucosphyrus* in night by human bait and none by animal bait thereby indicating a decided preference for human blood. McArthur (*loc cit*) has shown that *A. leucosphyrus* adult female entered the house long after midnight fed on their sleeping victims and after a short rest fled quickly away to their undiscovered outdoor resting places before dawn. He also recorded that if this mosquito entered a human bait trap it did not wait long enough to get caught which explained its relative rarity in the traps. It was also observed by him to be present and feeding on sleeping persons in houses where the human bait trap was being operated unsuccessfully. Macan (*loc cit*) notes that the proportion of the *leucosphyrus* adults caught near man was disproportionately large to the number of larvae found in the vicinity and this signifies that the adults from the nearby breeding places were attracted to man and thus converged to the human habitation. He fixed the time of biting activity of *leucosphyrus* as to start about 22.00 hours and to reach the maximum between 24.00 and 01.00 hours. Colless (1953b) also found peak feeding time to be at midnight. The proportion of mosquitoes caught before and after 01.00 hours being almost equal. But between 02.00 and 03.00 hours the mosquitoes suddenly departed from the dwellings and were very rare in catches after 03.00 hours.

Anthropophilic index —Walch (1932) established by precipitin tests that 90 per cent out of 102 specimens of *A. leucosphyrus* tested had human blood in them and he also observed that this species readily fed on man. Ramsay *et al.*, (1936) in Assam and Northern Bengal found by precipitin tests that 75 per cent of 102 *A. leucosphyrus* were tested to have human blood. McArthur (*loc cit*) noted that this species had a much greater preference for human blood with an anthropophilic index of about 90 per cent.

Flight range —Senior White (1926) reported that Bais in 1919 collected *A. leucosphyrus* from houses in Dutch East Indies 800 meters away from the nearest breeding place. McArthur (*loc cit*) and Colless (1953a) have taken the distance from the jungle margin to villagers where *A. leucosphyrus balabacensis-bornemalana* becomes

a negligible quantity as the effective flight range. They have concluded the effective flight range of *A. leucosphyrus* to be half a mile and range of diffusion to be more than a mile.

RELATION TO MALARIA

Longevity and swarming — No information direct or indirect is available regarding the longevity and swarming habits of *A. leucosphyrus*.

A. leucosphyrus is considered to be an important vector in Assam. In Digboi area (Assam), Crawford in 1938 (as reported by Clarke and Choudhury, 1941) noted for the first time natural infection in *A. leucosphyrus*. This was later confirmed by Clarke and Choudhury (*loc cit*). Terrel (1943) incriminated this mosquito as a vector in the same area. Outside India *A. leucosphyrus* is considered to be a vector of considerable importance in Borneo. McArthur (1950a) records *leucosphyrus* as the only anthropophilic species connected with hyperendemic malaria of the jungle ravines in Borneo. The positive dissections recorded so far available are given in Table 1.

CONTROL

The paucity of information about the bionomics, the rarity in routine catches and the reputation as a harmless mosquito has been responsible in diverting the attention of various workers from the control of *A. leucosphyrus*. It is now conclusively proved by McArthur (1951) that this species is not as innocuous as it was believed to be, wherever it is present and whenever dissected in adequate numbers it has been found to be infected and to be the carrier. Its vectorial capacity has been very much underrated previously.

Successful control of *A. leucosphyrus* is reported by McArthur (1947) who employed naturalistic methods like jungle clearing and admission of sunlight into the breeding places. Earlier he failed to control them by the usual larvicidal methods, and has since stressed the use of herbicides or weedicides.

Gilroy (1951) in his field trials with suspensions of DDT and BHC in Assam against this species came to the conclusion that where the local conditions require six weekly replastering of walls 10 mgms BHC or 45 mgms DDT sq ft were equally successful in

TABLE I

| Observer | Area | Number | | Positive | | Total | Percentage positive |
|-----------------------------|---------------------------------|----------|-----|----------|-------|-------|---------------------|
| | | disected | Gut | Gland | Gut + | | |
| Bais (1919) | Santar Estate, Sumatra | 235 | — | — | — | 4 | 1.7 |
| Doorenbos (1931) | Kisuran, East Sumatra | 504 | — | — | — | 5 | 1 |
| Stoker (1934) | Sarang Tioeng, Borneo | 57 | 6 | — | — | 6 | 11.26 |
| Goelarto (1934) | Kg Mocara Pangean, Dutch Borneo | 13 | — | — | — | 1 | 7.69 |
| Toumanoff (1936) | Indo-China | 77 | 1 | — | — | 1 | 1.29 |
| Clarke and Choudhury (1941) | Digboi area, Assam | 135 | 2 | 2 | 1 | 5 | 3.7 |
| " | " | 82 | — | 4 | — | 4 | 4.9 |
| McArthur (1941) | Tamburnam | 639 | 7 | 13 | — | 20 | 2.97 |
| Overbeek (1941) | Colonization Boenta Celebes | 1874 | 281 | — | — | 281 | 15.04 |
| Macan (1948) | Tamu Kabaw Valley, Burma | 172 | — | 4 | — | 4 | 2.33 |
| McArthur (1949) | Labuan | 727 | 9 | 16 | 5 | 30 | 4.26 |
| " (1950b) | Labuan | 1109 | 6 | 8 | — | 15 | 1.35 |

controlling this mosquito Where a longer cycle of spraying is desirable 20 mgms gama BHC was preferable to any DDT dosage

In Sarawak (Borneo), WHO started control of *A leucophyrus balabacensis* by residual insecticides in 1953 the results of which are not yet available Colless (1953b) tried a small experiment with residual insecticides but were not conclusive

REFERENCES

- Allman, S L (1945) Personal communication to M Arthur (1951) *Trans Roy Soc Trop ed Hyg* 44 p 683
- Bais, W I (1919) Quoted in *Parasitology* edited Swellengrebel, N H and S, de Garf (1910), p 180
- Baissas, F (1936) *Philipp J Sci*, 56 p 65
- Christophers S R (1912) *Sc Mem Govt of India LVI* Govt Press Calcutta
- Clarke R H P and Choudhury M A (1941) *J Mal Inst*, 4 p 103
- Cogh H (1903) *J Bombay Nat Hist Soc*, 15 p 327
- Colless D H (1948) *Proc Linn Soc NSW* 73, parts 3 4
- Idem* (1953a) *Med J Malaya*, 7, p. 179
- Idem* (1953b) *Ann Trop Med Parasit* 47 p 261
- Covell G (1927) *Ind Med Res Mem*, 7 p. 44
- Idem* (1944) *J Mal Inst Ind* 5, p 410
- Doorenbos W B (1951) M D Thesis Univ Leyden quoted by McArthur, J (1951) *Ind. J Mal* 4, p. 391
- Idem* (1931) *Geneesk Tij Med Ind* 71, p 1458
- Gilroy A B (1951) *Ind J Mal*, 5 p 171
- Goelaras (1934) *Geneesk Tij Med Ind* 71, p 1458
- James S P (1903) Cited in F V Theobald Monograph of the Culicidal of the World, *Brit Mus Nat Hist Lond*, 3 p 51
- James, S. ■ and Stanton, A T (1912) *Paludism* 5, p 60
- Lalor, N P O G (1912) *Invest Mal at Kyanhpyr* Govt. Press, Rangoon
- Macan T T (1948) *Bull Ent. Res* 39 p 237
- McArthur, J (1941) *Monthly Reports of Malaria Research Deptt Tambunan* Quoted by McArthur (1951), *Ind. J Mal* 4, p 391
- Idem* (1947) *Trans Roy Soc Trop Med Hyg*, 40 p 537
- Idem* (1949) *Annual report on the work of Malaria Research Deptt, 1948* Labuan, quoted by McArthur *Ind J Mal*, 4, p 391

- Idem.* (1950a) *Ind J. Mal*, 4 p 391
- Idem* (1950b) *Annual report on the work of Malaria research Deptt 1949*, Labuan
- Idem* (1951) *Trans Roy Soc. Trop. Med., Hyg.*, 44, p 683.
- Overbeek, J. G. (1941) Quoted by McArthur, J., *Malaria Borneo* (Manuscript)
- Muri I M (1931) *Ind. Med. Res. Mem* 21, p. 136.
- Ramsay, G. C., Chandra, S. N. and Lamprell, B. A. (1936) *Rec. Mal. Surv. Ind.*, 6, p 49
- Reid, J. A. (1949) *Proc. Roy. Ent. Soc. Lond. Ser. B*, 18, Pts 3-4 p 42
- Roper, R. (1914) *Bull. Ent. Res.* 5, p 137
- Senior White, R. (1926) *Ibid.*, 16, p 187
- Stoker, W. J. (1934) *Geneesk. Tij. Ned. Ind.*, 74, p 1342.
- Tetrell, C. G. (1943) Quoted by McArthur, J. (1951) *Malaria in the Afjal Road area of the Luabai Hills Frontier. Typed Rept. Hq. Med. Unit of Assam.*
- Toumanoff, C. (1936) *Coll. Soc. Path. Exot. Monog.*, 4, Masson and C^{ie} Paris
- Venhuis, W. G. (1942) *Geneesk. Tij. Ned. Ind.* 82, p. 99
- Walch, E. W. (1932) *Ibid.*, 72, p 682.

X. A *CULICIFACIES*, GILES, 1901

BY

M L BHATIA

AND

K S KRISHNAN

(Malaria Institute of India, Delhi)

[October 29, 1956]

INTRODUCTION

THE identity of this mosquito was established in the year 1901 by Giles who gave a brief description of specimens obtained from Hoshangabad, Central Provinces and the Berars Deccan (the present day Madhya Pradesh). He gave the name *culicifacies* to it because in the living state its resting posture resembles that of a culicine mosquito. It was proved to be a vector of malaria by Cornwall in 1902 for the first time.

SYNONYMY

- (a) *A. histon* Giles 1901 corrected by Theobald (1903)
- (b) *A. indica* Theobald 1901 corrected by Theobald (1903)
- (c) *A. punjabensis* James 1911 corrected by Christophers (1916)

RECOGNIZED VARIETY *A. CULICIFACIES ADENESIS* CHRISTOPHERS 1924

Many workers have suspected from time to time that *A. culicifacies* is composed of at least two forms, one having vectorial capacity while the other is innocuous. Specimens of *culicifacies* from areas in India where it is known to be a vector and from areas where it is not have been intensively studied for comparison (Russell and Rao 1942, Pal 1945) but no significant morphological difference has so far been detected in the egg, larva or adults. The question of the possible existence of the sub species is still unsolved.

DISTRIBUTION

The species is widely distributed in the Indian region. Eastwards it extends through Assam, Burma and Thailand to the Plateau of Yunnan in China. Southwards it is predominant in Ceylon. In the westerly direction it is distributed over Pakistan (West Punjab,

Sindh and Baluchistan), Afghanistan, Aden, Muscat (Arabia), Palestine, Iraq and North Persia. Macan (1930) believed that specimen collected by Keys at Bushire in North Persia was wrongly designated *A. sergenti* and was really *A. culicifacies*. It has been pointed out by one of the present authors that the original home of this species apparently lies somewhere in India with Delhi and Pattukotta in the axis (Bhatia, 1955).

BREEDING PLACES

The preferential breeding places of the species are fresh rain-water pools, irrigation channels, pools in river bed, borrowpits and cemented tanks in most localities. In South eastern Madras the types of breeding place which account for the bulk of *culicifacies* breeding are irrigation canals, wells and waste irrigation waters. From these three types combined, Russell and Rao (1940 and 1941) obtained "nearly 70 per cent of all larvæ collected and about 58 per cent of all times taken". It is one of those species which is wellknown for its ability to breed in a great variety of breeding places. In the Ennore Nellore coastal areas of Madras, shallow pits dug for watering young *Casuarina equisetifolia* plants have been described as virtual nurseries for the species (Russell and Jacob, 1939 a). The soil of this area is sandy and relatively infertile. In Delhi area different types of breeding place of the species were classified by Covell (1939) as (a) excessive irrigation water, associated with canal system coupled with interference with natural drainage by embankments for railways, roads and canals (b) the annual rise of water level in the river Jamuna resulting in heading up of storm water drains, (c) large number of residual pools, aftermath of receding flood in the river, (d) vast number of excavations in the form of borrow-pits, pits in brick fields and quarries, (e) domestic breeding places in the form of water collections fed from hydrants and leaky sluice-valves, ornamental waters and unused swimming pools.

In a reclamation area of Bombay State it has been found breeding in brackish water which contained up to 25 per cent of sea water (Chalam 1924). According to Young and Majid (1930) the soil in many parts of Sind (Pakistan) is impregnated with alkaline salts of magnesium, calcium and sodium known as "Kallar". Water standing on such soils, rich in these salts (Kallar) affords very suitable environment for *culicifacies* breeding. These authors also observed

- * that the addition of leaves falling from Babool trees (*Acacia arabica*) on the water surface, along the edges of canal and their tributaries created highly favourable culture medium for the larvæ

In Punjab, the species has been found to breed in dirty cattle ponds, muddy borrowpits and roadside drains (Ramsay and MacDonald, 1936). These workers also noted that high sub-soil water table produces ideal swamps for *culicifacies* breeding. Preferential breeding places reported by Davy (1912) are weedy pools under shade of trees and water in slow motion through tufts of grass. The larvæ also flourish in irrigation channels with a considerable central velocity (2.4 miles per hour), provided the banks have bays and are grassy. *Culicifacies* breeding in moving water was also observed by Mulligan and Baily (1936) in Quetta (Pakistan), where chief breeding situations were in connection with open irrigation channels arising from springs, wells, river and karezes. The breeding was predominant in bays and backwaters along the edges of the channels. Mulligan and Baily (*loc cit.*) however found that breeding was less prevalent in water under the shade of trees and in underground or partly underground water of karezes. According to De Burca (1946) in Jubbulpore, (Vindhya and Satpura Ranges) it is essentially a stream breeder. The larvæ are found in very large numbers in medium sized streams with sandy edges devoid of standing vegetation. In smaller streams they particularly abound among *spirogyra*. It has been noted by Barber and Rice, (1938) in Poona that breeding in wells is resorted to during the hot and dry weather when the favourable breeding grounds dry up. In Pattukottai (Madras), the species breeds prolifically in wet fallow and young ricefields. Russell and Rao (1942 a) have shown that *culicifacies* breeds abundantly in rice fields before and immediately after planting but when the plants attain a height of 12 inches it is no longer to be found there. The experiments of these workers have revealed that the height of dense shade over the breeding places by itself has no influence, either in attracting or repelling the ovipositing females. Mechanical obstruction is the real determining factor. Rao and Ramoo (1942) reported successful inhibition of *culicifacies* breeding along the margins of canals in Pattukottai (Madras) by cultivating *Vitex negundo* a perennial shrub on the canal banks. The dense foliage of *Vitex negundo* creates both shade and mechanical obstruction. The latter is probably a more important factor than shade in preventing *culicifacies* breeding. In Kashmir, the species is

in hill streams with pebbles in their beds (Jacob 1950) Still another type of breeding place = concrete cistern (Dow, 1953) In Muscat the favourite breeding grounds are wells (Gill 1916) Aden (Hinterland) also presents a similar condition where var. *adenensis* breeds in wells and pools in bed of streams (Christophers 1924) In the villages along the Arakan coast of Burma, *culicifacies* has been reported (Garewal 1937) breeding even in domestic water containers such as earthenware vessels and old tins But this finding has never been confirmed by any other worker Mehta (1934) in his experiments on *A. culicifacies* with natural waters containing different amounts of free ammonia and solutions of ammonium carbonate concluded that oviposition took place indiscriminately in the laboratory in waters with up to 6.6 per million saline ammonia Observations of Russell and Rao (1946) on the ecology of larvae of *A. culicifacies* in seepage filled borrow-pits in Pattukottai showed that no definite relationship existed between the fluctuations in the density of larvae and any one of the following factors: depth of water, rainfall, microscopic vegetation, hydrogen-ion concentration, carbon dioxide, dissolved oxygen, alkalinity, hardness, chlorine, ammoniacal nitrogen, nitrates, nitrites, sulphates, phosphates, iron and poisonous metals The important factors which had significant bearing on the increase or decrease in the number of larvae were

- (1) Ageing of the pits: The highest numbers of larvae were found when the pit was newly dug. There was a decline in the number as the pit grew older.
- (2) Plankton and amorphous matter: Marked decrease in the number of larvae was associated with increase in total plankton and amorphous matter. Individual planktonic organisms however had no relation to *culicifacies* breeding but blue green algae seemed to have detrimental effect.
- (3) Turbidity: Water of the newly dug pits was turbid and of the old ones clear. Certain amount of turbidity (40 per 100 c.c.) may be favourable for the species.

In the turbid and mud coloured canal waters of South Eastern Madras the species has been reported to thrive (Russell and Rao, 1940).

* It is, however, an important factor in creating fresh pools which are prolific breeding grounds of the species.

Rain-water pools on clay and sandy soil are ideal for *Culiseta* breeding but on peaty soil it is not so (Russell and Jacob, 1939b)

Water temperature —Most species of anopheline larvæ may be found under field conditions in water whose day-time temperature near the surface is within a range of 24° to 35° C *Culiseta* larvæ however may be found thriving even at higher temperatures Russell and Jacob (1939c) reported that the species was found in water of casuarina pits exposed to sun having a surface temperature as high as 38° C Eggs and first stage larvæ are more resistant to high temperature, than fourth stage larvæ Thomson (1940) determined the thermal death point of the fourth stage larvæ of different anopheline species He defined the thermal death point as the lowest temperature at which all larvæ were killed by an exposure of five minutes the temperature being raised slowly over a period of one and half to two hours He found that in *Culiseta* the thermal death point was as high as 44.0°C which was second only to that of *A. vagus* whose thermal death point was 44.5-45°C Laboratory observations of Pal (1945a) show that *A. culiseta* larvæ can tolerate temperature upto 43.3°C The most favourable temperature according to him however ranged between 28°C and 32°C, the optimum being 32°C

ASSOCIATION OF SPECIES

Association of *A. culiseta* larvæ with those of other anophelines has been studied by Russell and Rao (1940) in South Eastern Madras Out of a total of 3014 positive larval collection made over a period of one and a half years the frequency with which the species was found by itself or in association with two other species was as follows

| Combination of species | | Time taken together | |
|------------------------|------------------|---------------------|-----|
| <i>Culiseta</i> | <i>Culiseta</i> | <i>Culiseta</i> | 942 |
| " | <i>subpictus</i> | <i>vagus</i> | 278 |
| " | " | <i>pallidus</i> | 217 |
| " | " | <i>annularis</i> | 120 |
| " | " | <i>varuna</i> | 107 |
| " | <i>pallidus</i> | <i>vagus</i> | 72 |
| " | " | <i>hyrcanus</i> | 68 |
| " | <i>subpictus</i> | " | 62 |
| " | " | <i>jamesi</i> | 58 |
| " | <i>annularis</i> | " | 42 |
| " | " | <i>pallidus</i> | 41 |
| " | <i>jamesi</i> | <i>vagus</i> | 31 |
| " | <i>varuna</i> | " | 26 |
| " | <i>hyrcanus</i> | " | 19 |

The number of times the species is found alone not associated with other species is significantly high (31.3 per cent times). Thus it is obvious that the species has its own preferred breeding grounds. Furthermore, the most frequently associated species is *A. subpictus*, which seems rather paradoxical at first sight but is in keeping with the fact that *A. subpictus* is found in a great variety of water collections.

OVIPOSITION

The process of egg laying in *A. culicifacies* resembles that of *Anopheles maculipennis* group described by Bates (1940). Russell and Rao (1942) showed that *A. culicifacies* in nature has the habit of ovipositing while flying and performing a hovering dance about two to four inches above the water surface. During the dance they never touch the water surface either directly or indirectly by resting on the neighbouring bank edge or on any floating material. They keep flying to and fro in relation to some fixed point. The flight movements are vertical as well as horizontal as the female drops eggs. Gravid females go to the breeding places at about 6.30 to 7 p.m. when it is dark enough to make them invisible to the unaided human eyes. They lay eggs all through the night up to about 5 a.m., the greatest number being laid during the first third of the night.

The average number of eggs that a wild caught female has been found to lay during different seasons at Pattukottai according to Russell and Rao (1942) are as follows:

| Season (1940-41) | Average number of eggs laid |
|------------------|-----------------------------|
| February-March | 131 |
| April-May | 111 |
| June-July | 135 |
| August-September | 105 |
| October-November | 115 |
| December-January | 123 |

This shows that there is no great difference in the fecundity of the females in relation to seasonal changes in that locality.

SWARMING AND MATING

The most important factor controlling the swarming and mating of this species seems to be ample space for orientation. In a space limited to 2 X 2 X feet size cages all attempts by different workers have failed to achieve fruitful results. Russell and Rao (1942) successfully induced it to swarm and mate in an aluminium wire screen cage with dimensions 40 X 20 X 10 feet. The cage was an outdoor one enclosing a small mud and thatch hut. Essential requisites of the mosquitoes for feeds, resting and oviposition closely simulating natural conditions were provided within the cage. Important points observed by these workers were as follows — Mosquitoes became active and left the diurnal shelter between 6.00 and 7.00 p.m. when a light meter at ground level facing the sky showed a reading of 5.0 foot candles. When the light intensity came down to about 2.0 foot candles swarming started with a single male performing dancing movements. Soon it was followed by a large number of individuals over a selected place to form a typical swarm. The swarms were very compact measuring about one foot vertically and 1.5 feet above the ground. The most remarkable feature of the swarms was the exact position within the wire netting cage where it always took place. It was always on an east to west line about 23 feet long of clear space without any obstruction and over dry earth. The dancing individuals in a swarm always showed a forward and backward floating movement facing east. Variable number of females could be found in the swarm but their number was always much smaller than those of males.

Number of individuals taking part in a swarm varied from 4 or 5 to more than a hundred. Position of male and female during copulation was end to end. Thus connected they slowly flew away from the swarm in all directions and separated on coming in contact with vegetation or other objects. Copulation was observed to last up to 15 seconds. It was also noted that sometimes mating took place even without the formation of swarms but the time and place selected for the purpose was the same as that of the swarms. It was also observed that the copulating females in most cases had taken a blood feed before mating. No clear relationship of meteorological condition and swarming was noted except that immediately before or after rain it did not occur.

RESTING PLACES

A. culicifacies is a predominately domestic species preferring human dwellings and cattlesheds for its daytime resting. Reports regarding the relative prevalence in cattlesheds and houses are rather conflicting. In Bengal (Timbers 1935) the number resting in houses was higher than that in cattlesheds. Senior White (1937) on the contrary found that in Jeypore greater number were to be found in cattlesheds than in human dwellings. Senior White et al. (1945) reported that the ratio of cattlesheds to house catches was opposite of what they found in a locality near the Western Ghats. Findings of Senior White and Das (1938) at Singhbhum hills and of Perry (1934) in Jeypore Hill tracts again go to show the preponderance of the species in cattlesheds. In Delhi urban area Afridi, Jawant Singh and Harwant Singh (1939) also found that the number captured from cattlesheds was higher than that from human dwellings although both shelters were in the same courtyard. That the species may feed in one place and rest in another is now well recognised. Afridi et al. (loc. cit.) have reported that human blood fed specimens of this species were at least twice as numerous in cattlesheds or combined human and cattlesheds as from purely human habitations. Similarly Senior White (1947) found that human blood fed specimens could be found not only from human dwellings but also from cattlesheds and even outdoor shelters. Larger percentage with human blood feeds were from cattlesheds. There is thus greater evidence to show preference of *A. culicifacies* for cattlesheds as daytime resting places. Apart from the proximity of the source of blood feed other factors which determine the resting places are the cool, dark and humid atmosphere protected from draughts. The climatic conditions most favoured by the species are a temperature range 77°-86°F in combination with relative humidity of 60-80 per cent (Pal 1943). Suitable ecological conditions may be encountered by the mosquito even in outdoor shelters. Instances are available which show that the species does utilise outdoor resting places. Perry (loc. cit.) found it resting in significant numbers amongst the roots of thick bushes in Jeypore hills. Senior White (1946a) found variable number of blood fed specimens taking shelter during daytime in nala banks in Singhbhum nala banks and bushes in Jeypore hills, caves and culverts in Hazaribagh and Korea Coalfield areas. The species is also known to utilize outdoor resting places to some extent in Baluchistan where they have been found in considerable

number in karezes and caves quarter of a mile or more away from human habitations (Mulligan and Baily, 1936). Evidence of *A. culicifacies* resting in outdoor locations has also been furnished by Rajendram *et al* (1950) in Ceylon. They could catch it by means of human baited traps in dense jungle in which there was scrub as well as high forests as far away as 4-7 miles from human dwellings. So far it has not been found under outdoor conditions in Delhi area and its environs in spite of repeated searches. The species is clandestine in its resting habits. It has been found hiding in holes and crevices, of the roof (James and Liston, 1911). Christophers (1933) has stated that it hides in holes among dungcakes and in chaff etc. It has been observed to penetrate deep into thatch of cow-sheds and even into the bristles of nail brushes (Clemeshaw, 1934). Recently a peculiarity observed by us in Vindhya Pradesh was that this species was seldom found in sheds where goats alone were kept. At Bushehr in Iran adult *A. culicifacies* have been found to rest in large concrete cisterns inadequately screened in which rain water is stored (Dow 1953).

Aryaratnam (1955) in Ceylon found that the least utilized situations inside houses were hanging clothes and other objects which is contrary to the findings in Delhi (Pal and Sharma, 1952). One of the situations most preferred by the species in domestic resting places observed in Delhi and Vindhya Pradesh is the underside of horizontal surfaces such as roof and shelves along the walls. Cobwebs along the corners and roofs are also the favoured resting places. Rafi (1955) has reported from Punjab, (Pakistan) that *A. culicifacies* was found uniformly distributed throughout the whole wall surface inside the room. This is at variance with Aryaratnam's (*loc cit*) observations in Ceylon where this species was found to rest mostly below six feet.

SEASONAL PREVALENCE

Fluctuations in the adult density of mosquitoes is interlinked with the larval habitats of the species. For this reason the most important factor is the extent to which the favourable breeding places are available. Afridi *et al* (1940) were of opinion that no definite relationship can be established between the meteorological condition and numerical variation in *A. culicifacies* density. But they believe that it is regulated by some unknown seasonal element. Russel and Rao (1941) were also doubtful of temperature and humidity having

great consequence in the seasonal fluctuation in the density of this species in Pattukottai area. The observations made by us in areas round Delhi during the past four years also show that meteorological conditions like temperature and humidity do not seem to have much significance on the numerical prevalence of this species. The extent of irrigation and irrigation seasons showed positive correlations with *A. culicifacies* density in Pattukottai. Rainfall is another factor which has important bearing on the seasonal prevalence of the species over wide areas. Heavy rainfall may flush away the favourite breeding places and result in reducing the adult population. On the other hand if it is of moderate intermittent type it may create and maintain large number of suitable breeding places to build up high adult density. This is well borne out by the observations of Brookeworth (1952) in Mysore State. The unknown seasonal element referred to by Afridi *et al.* (1940) may perhaps be explained in the light of Russel and Rao's (1942b) work who showed that freshly formed water collections devoid of amorphous matter were the most prolific breeding sites of this species. Such collections are associated with rainfall and irrigation water.

The seasonal prevalence of *A. culicifacies* for undivided India as a whole was fully discussed by Afridi and Puri (1940). They divided the country into seven regions and have classified the seasonal prevalence according to the data published by workers in those different regions. These regions and the seasonal prevalence of the species are briefly summarised below.

(A) North West Frontier Province and Quetta (Pakistan) — The period of low prevalence is from January to May and peak density being in September-October. After which it begins to decline and comes to a very low level in December.

(B) West and Central Punjab Derajat (V W F Province) — In this region the months of low density are December, January and February. During the rest of the period there are two peaks of high density. The first peak is during the spring months March, April and the second one which is higher during September-October.

(C) South East Punjab, Sindh, Western U P, South E P, Orissa, Mysore hill tracts, Hyderabad State and parts of Madhya Pradesh — Here the species occurs in significant numbers in

the year though periods of comparatively low densities are January-February and May June with two peaks one in March April and the other September

(D) *Eastern Terai Assam Bengal W Coorg Malabar (hill areas) and S W Coorg*—Here the species occurs throughout the year but with high prevalence during February to May

(E) *Eastern U P Riverain Tracts in U P and N Bihar*—In this region the months of low density are July August with two peaks first in April May and the second in October November

(F) *Madras inland tracts S E Coast E Coorg and low lying areas of Malabar*—The month of low density in this area are July September with peaks in December-January

(G) *Vizagapatam area and Madhya Pradesh*—*A. culicifacies* occurs throughout the year with prolonged period of high prevalence from July to December

Russel and Rao (1941) have however shown that in Pattu kottai Tanjore Distt the period of greatest prevalence of the species was in August September. This observation is not in agreement with type F of the maps published by Afridi and Puri (1940)

In addition to the above Viswanathan (1950) has given the seasonal prevalence of this species in some of the areas of Bombay State

In Bijapur Distt the highest density is in mid September and the numbers fall off rapidly from December. In Nasik Distt the density of this species remains high from November to July. In West and East Khandesh districts the highest prevalence is from August to October while in Poona and Sholapur Distts fair number of *A. culicifacies* occur throughout the year but the peak is from June to November and there is rapid decline from October. In Durg Distt the density of the species remains high all through the year highest being in July. In Broach Distt, *A. culicifacies* shows a sharp increase in density in August while the peak is reached in November. Fair numbers are maintained till the end of March

In Ahmadnagar Distt *culicifacies* density remains high all through the year except in May

Jaswant Sing and Jacob (1944) in N Kanara found the largest number of this species in April and June and least in October

DENSITY

A. culicifacies being a predominantly zoophilic species has to have a high adult density to be able to transmit human malaria. The statement of Viswanathan (1930) that the vectorial capacity of this species "in any area is determined solely by its numerical prevalence" does not always hold good. It has to be associated with the longevity factor. Where this species is a vector its density is no doubt high but on the other hand instances are available where high density prevails in the absence of malaria transmission. One such instance is provided by Viswanathan himself (*loc cit*) in his report that in Khandesh District (Bombay), the species continues to show fairly high density during the hot and dry months of February to April without malaria transmission. A still more striking example of this was recently met with in Vindhya Pradesh during a survey in April 1954. Of the different areas examined, two that showed highest *culicifacies* densities of 131 per man hour at Nangayi and 134 per man hour at Marwas were among those which showed the lowest spleen rates—9 per cent in the former and 18 per cent in the latter. This just goes to show that high density alone is no criterion of its ability to transmit malaria. It is explainable by the meteorological conditions which effect the longevity of the species.

The classical work of Russel and Rao (1942b) on the density of *A. culicifacies* in relation to malaria endemicity has provided a very valuable index. Comparing the *culicifacies* densities of two contiguous areas (in South India) meteorologically identical but one malarious and the other non-malarious they came to the conclusion that provided other factors were favourable 50 mosquitoes captured per man hour represented the minimum critical density of the species. They claim that below this figure no transmission of the disease can take place.

Some of the figures that are available on the per man hour density of *A. culicifacies* during transmission season in different areas are presented below—

- (1) In the year 1939-41, during which malaria in Delhi was practically negligible, the per man hour density of *A. culicifacies* never exceeded 3.4 (Pal, 1945b). There was a severe outbreak of malaria epidemic in this State in autumn of 1942 showing a rise in per man hour density

to 11.6 in September. In the same month of the post epidemic year 1943 it was even higher, 11.7 25.0

- (2) Viswanathan (*loc cit*) reports that this species in Bijapur District (Bombay) during the entire transmission season has a density at levels several times higher than 5.0 per man hour in mid September. In Dharwar District it does not go much above 8 or 9 per man hour.
- (3) At Tuvarangurichchi in Tanjore district (S India) during the transmission season July to November 1939, Russell and Knipe (1940) showed that the density of species varied between 7.5 and 28.4 per man hour highest being in August.
- (4) Average figure for density of the species in the entire Pattukottai taluk derived from 1937 to 1940 by Russell and Rao (1941) are

| | | |
|-----------|------|--------------|
| July | 11.0 | per man hour |
| August | 25.7 | " |
| September | 20.3 | " |
| October | 11.6 | " |
| November | 9.9 | " |

The highest level reached was 40 per man hour in August of 1939 and 1940 (Russell and Rao 1942).

- (5) Viswanathan and Gadre (1950) reported that the density in Ahmedabad District (Bombay) during September varied from 13.0 to 25.8 per man hour.

In most of the areas cited above, the density of the species during non-transmission periods is known to remain invariably below the critical level of 5.0 per man hour. As such it may be regarded as a further proof in support of the conclusion derived by Russell and Rao (1942).

The index 5.0 per man hour may thus be adopted with advantage for determining the timely application or reapplication of control measure in areas of *A. culicifacies* transmitted malaria.

LONGEVITY

Atmospheric temperature and humidity play an important part in determining the longevity of a mosquito. The longevity increases as temperature decreases and more especially as relative

humidity increases Mayne's (1930) studies on *A. culicifacies* under laboratory conditions indicated that adults lived longer at low humidity provided the temperature was also relatively low. He found that for a relative humidity in the range of 80 to 88 per cent the favourable temperature was 80°F while at 57-62 per cent relative humidity it was 67°F. The duration of adult life with these combinations were.—

| Humidity (Per cent) | Temperature | Longevity in days |
|---------------------|-------------|-------------------|
| 80-88 | 80°F | 7-21 |
| 57-62 | 67°F | 10-21 |

Reduced humidities at the same temperatures brought about a marked reduction in the longevity of *A. culicifacies* as follows

| Humidity (Per cent) | Temperature | Longevity in days |
|---------------------|-------------|-------------------|
| 40-46 | 80°F | 1-4 |
| 51-52 | 67°F | 3-4 |

Covell and Bailey (1930) in Sind and Macdonald and Majid (1931) in Karnal concluded from the absence of sporozite infections that the longevity of the species was less than ten days during dry months. Hicks and Majid (1937) also held the opinion that the duration of adult *A. culicifacies* varied inversely as the saturation deficiency in the atmosphere. Observations under laboratory conditions by Pal (1943) showed that at low temperature 55°F (12.9°C) high humidity (80 to 100 per cent) was advantageous for the promotion of longevity and adult females lived for four to eight weeks. He also reported that at higher temperatures 25°C (77°F) and 30°C (86°F) survival at a relative humidity of 60 per cent was considerably longer than at either higher or lower humidities. At 25°C the longevity was 14 to 23 days and at 30°C it was 6 to 18 days. Field studies on longevity of *A. culicifacies* by Afridi *et al.* (1940) by releasing a large number of gold dusted specimens near Karnal (Punjab) revealed that specimens released in November and December lived upto 56 days. Those released in dry months particularly May and June were very short lived. They also found that the longest period any adult remained alive in caged condition was 49 days in November and December and the longest average life of about 24 days was also in the same months. Bose (1934) surmised that *A. culicifacies* lived at least four months from July to November in the adult form because no larval breeding could be detected

Vectors of Malaria in India

during the period in a flooded area in Burnagar (Bengal) Siddons (1944) studying infection of *A. culicifacies* with different species of human plasmodia came to the conclusion that a lower temperature within the range of 94 to 70° F particularly when combined with increased relative humidity increases the period of survival. Russell and Rao's (1942e) finding on the longevity of *A. culicifacies* under simulated natural environments in Pattukottai agree in general with figures obtained by Afridi *et al* (1940) from Northern India (Karnal) under field conditions. Maximum longevity of the females in different months in the two areas compare as follows

| Months | Maximum longevity in Karnal | Maximum longevity in Pattukottai |
|-----------|--------------------------------|-------------------------------------|
| May | | |
| June | 9 | 11 |
| July | 14 | 14 |
| August | 24 | 24 |
| September | 14 | 33 |
| October | 25 | 23 |
| November | 32 | 32 |
| December | 45 | |
| | 56 | |

There were marked differences in the temperature and humidity of the two areas but their combinations were similar to the corresponding longevity figures which are more or less the same. Russell and Rao's (1942) work also reveals that at Pattukottai the maximum longevity of the species varied from 8 to 11 days during May to early June. From mid June to mid July it was 13 to 16 days. In the later months up to end of November it always remained above 21 days. Males are very short lived. The maximum longevity noted for them is eight days. The most important feature of Russell and Rao's (1942) studies was regarding the rate of mortality of adult females. They found that death rate among them was 60 per cent every two days and reduction in population took place by geometric before the. Nearly 97 per cent of *A. culicifacies* die the remaining three per cent of their

population have any chance of carrying on malaria transmission. They calculated that the probable duration of life of the species was two days and the average life was only four days. But in every batch there were invariably one or two specimens which were much longer lived than the rest. As this species is known to transmit all three species of human plasmodia its density in any particular area must be very high to make its three per cent (longlived) population effective transmitter.

BITING TIME

Clyde (1931) reported from his observation in U.P. Terai that the species bite human beings during day as well as night time. King and Krishnan (1929) recorded similar observation in Nellore District (Madras) but subsequent workers elsewhere have not been able to confirm these findings. Senior White (1938) in the Jeypore Hill tracts found that the species bite mainly around midnight very little at 2.30 a.m. and none at all at 4.30 a.m. Observations made at Delhi by Afridi and Puri (1940) were in agreement with those of Senior White. Further investigations made in Delhi by Pal (1945) showed that the greatest biting activity of the species took place between 22.30 and 01.00 hours gradually decreasing after midnight.

FLIGHT RANGE

Russell *et al.* (1944) carried out intensive experiments on the determination of the flight range of the species in Madras state. They took 207,800 *culicifacies* specimens marked them with Majid's (1937) dusting technique and released them at a central spot. Recaptures were made from 80 calf baited traps in concentric circles placed at varying distances. The conclusion of their experiments was that the total flight range of the species in Madras was between 1.5 and 1.75 miles.

Earlier workers judged the flight range from their observations on the distances traversed by the species from the breeding places to the adult resting places. Stephens and Christophers (1902) believed the flight range to be limited to only a quarter of a mile at Nagpur. At Mianmir near Lahore however Christophers (1904) concluded that the species was probably capable of covering distances of half a mile or more during later part of malaria season. Lindberg (1935) regarded the dispersal range in Hyderabad

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(Deccan) to be 1,100 yards (five furlongs) James (1923) at Mian-mir found it restricted to 600 yards (2/31 miles) only Bose (1934) at Birnagar (Bengal) and Mulligan and Baily (1936) at Quetta (Pakistan) found the dispersal of the species not exceeding half a mile Afridi *et al* (1938) found in Kutch that adult *A. culicifacies* remained strictly confined to the immediate neighbourhood of the breeding places

To sum up the findings of different workers it may be said that the flight range of the species is normally about half a mile but may extend up to 1/75 miles when climatic conditions are exceptionally favourable Raghavan and Krishnan (1949) have given evidence of passive transportation by country crafts of *A. culicifacies* over long distances along the Buckingham Canal in southern India

ALTITUDE

Although *A. culicifacies* is generally reputed to be a plains species, it has been found to occur in some areas at high altitudes also Davy (1912) found it to occur in Quetta area (Pakistan) at altitudes between 5,500 to below 6,500 feet Graham (1912) recorded it at 6,355 feet above sea level in Nainital Mulligan and Baily (1936) established that *A. culicifacies* was one of the three important vectors of malaria in Quetta areas at 5,000–6,000 feet altitude Jacob (1950) found that the species is able to transmit the disease in Kashmir only up to an altitude of 4,000 feet Clemeshaw (1927) reports an out break of malaria due to this species at an altitude of 3,000 ft in Travancore The record of highest altitude at which a single specimen of this species was caught is 7,500 feet in Murree hills in Pakistan (Gill 1923) Afridi and Puri (1940) reviewed data from southern India (Malabar and the Nilgiris) to show that at high altitude the species prevails for a shorter period in the pre-monsoon months in contrast to lower altitudes where it occurs for a longer post monsoon period

For chalking out favourite haunts of the species one needs to look for areas with moderate or scarce rainfall rather than altitudes In a hill tract in Mysore State, Brooke Worth (1953) for his studies on the anopheline fauna selected three areas each having an altitude of 3,000 feet but with marked differences in annual rainfall—223, 83.19 and 48.23 inches With regard to *A. culicifacies* he found that

the incidence of the species was extremely low in the high rainfall area compared to the intermediate and low rainfall areas

HIBERNATION AND AESTIVATION

Neither of these two phenomena seem to occur in the life of *A. culicifacies* in any part of the plains of India. Covell and Bailey (1930) believed that there is a period of aestivation in the life of this species when the temperatures are above 90°F. But no supporting evidence has been found by any subsequent workers. In Delhi area which has very hot summer and severe cold winter months this species remains active throughout the year though there are marked fluctuations in their numerical prevalence. This is based on the following observations made by us under field conditions extending over a number of years —

- (a) All stages of this species viz. larvæ, pupæ and adults are found throughout the year
- (b) Blood fed females are available all through the year
- (c) Ovaries in all stages of development are observed in wild caught specimens in all the months
- (d) Oviposition has been obtained from the wild caught gravid females in the hottest as well as the coldest months of the year

Venkat Rao (1947) showed that in *A. culicifacies* there exist a phenomenon of gonotrophic discordance in which some females required more than one blood meal for the maturation of the ovaries.

It is well known that certain percentage of mosquitoes may not be able to take a complete blood meal during the course of a single night and another blood meal is taken the following night to mature their ovaries. This has been fully discussed by Jaswant Singh and Mohan (1951).

ANTHROPOPHILIC INDEX

Results of large number of precipitin tests on blood samples from *A. culicifacies* collected from the different parts of the country have been recorded by various workers. These are presented in Table I. It will be seen that the species is predominantly zoophilic.

TABLE I
Anthropophilic index

| S No | Investigator | Place | Year | Anthropophilic index per cent | | Remarks epidemic or non epidemic year |
|------|---|---|----------------|-------------------------------|----------------------|---|
| | | | | On positive reaction | On total examined | |
| 1 | Afridi Jaswant Singh and Harwant Singh (1939) | Delhi | 1937 | 1.8 | | N ep * |
| 2 | do | Delhi | 1938 | 9.93 | | N ep. |
| 3 | Barber and Rice (1938) | Poona | 1937 | 1.9 | | N ep |
| 4 | Covell and Jaswant Singh (1943) | Delhi | 1942 | 22.3 | 20 | Ep. |
| 5 | M I I Report (1948-50) | Tirumalapur Hyderabad (Dn) | 1946 and 48 | | 24 | N ep |
| 6 | do | Bellary (Madras) | 1948 | | 10 | N ep |
| 7 | do | Munrabad (Madras) | 1949-50 | | 32 | N ep |
| 8 | do | Haldwani (U P) | 1950 | | 50 | N ep |
| 9 | do | Chieng Mai (Thailand) | 1949 | | 51.7 | N ep |
| 10 | Ramsay Chandra and Lamprell (1936) | Assam and N Bengal | 1936 | 47.3 | 29.0 | N ep |
| 11 | Russell and Jacob (1939) | Ennore (Nel lore Coastal area) | 1937-38 | 80.0 | 34.0 | N ep |
| 12 | Russell Menon and Rao (1938) | Pattukottai | 1937-38 | 0.25 | 0.15 | N ep |
| 13 | Russell and Rao (1942) | do | 1942 | 2.5 | 1.50 | N ep |
| 14 | Senior White (1947) | East and Central India (Singhbhum Chatkora Korea and Vizagapatam) | 1947 | 12.9 | | N ep |
| 15 | Senior White and Venkat Rao (1943) | Vizagapatam | 1943 | 10.1 | | N ep |
| 16 | do | Jeypore hills | 1938-43 | 25.9 | | N ep |

* Ep=Epidemic

N ep =Non epidemic.

MAXILLARY INDEX

Roubaud (1921) was the original propounder of the theory regarding the blood preferences of anophelines in relation to the number of teeth present on their maxillæ. The critical figure for the maxillary index (average number of teeth on the maxilla) was fixed by him at 14. He claimed that an index of 14 or less was associated with human blood preference and 14 and above indicative of cattle blood preference. Considerable controversy exists regarding this claim and literature on the subject has been well reviewed by Senior White (1937a). Maxillary index of *A. culicifacies* was found by him to be 12.9 for the country as a whole. Of the 200 maxillæ examined the number of maxillæ in different detention groups were as follows —

| Detention | | Number of maxillæ |
|-----------|----|-------------------|
| below | 10 | 0 |
| | 10 | 1 |
| | 11 | 16 |
| | 12 | 60 |
| | 13 | 67 |
| | 14 | 43 |
| | 15 | 13 |
| above | 15 | 0 |

Similarly Pal (1945 b) found the index at Delhi to be 12.6. Certain amount of bilateral asymmetry does occur in the number of teeth on the pair of maxillæ of the individual mosquito specimens.

A comparison of the maxillary index of *culicifacies* from human baited traps and buffalo baited traps at Vizagapatam showed no significant difference. In the former it was 13.2 and latter 13.3 (Senior White and Rao, 1943). Furthermore Russel and Rao (1942) found that there was no difference in the maxillary indices of this species caught from malarious (Pattukottai) and non-malarious (Tanjore Delta) areas. In the former, the index was 11.79 and in the latter 11.87.

Although paucidentate, (index less than 14) we know that the species is predominantly zoophilic which is in variance with

Roubaud's theory : Moreover there are many species in India which are confirmed *non-vectors* but show *paucidentate* condition

Therefore the use of this index seems to be of very little aid, at any rate in the case of *A. culicifacies*, either in determining its food preference or its vectorial status

The suggestion made by Roubaud Toumanoff and Gaschen (1933) that the working out of maxillary index is more valuable than actual discovery of infections among mosquitoes cannot be accepted at least so far as *A. culicifacies* is concerned

RELATION TO MALARIA

Christophers (1933) was of opinion that *A. culicifacies* could be regarded as an important vector wherever it was found. It was, however, disapproved by Senior White (1937, 38) who showed that it did not take any part in malaria transmission in the highly endemic regions of Jeypore Hill tracts and other large areas of East Central India where it is found in large numbers. The species occurs throughout the country but its vectorial capacity is limited to Peninsular and North Western India. In Ceylon this is the only vector. It is to be found in small numbers in Burma, Thailand, Indo China and South China and is not considered to be a vector of any importance. A single specimen with oocysts in the gut found at Lahats, Yunan led to its being considered as suspected vector in that area (Gaschen 1931). In the westerly direction the vectorial capacity of the species extends through Afghanistan to perhaps Muscat in Arabia. It is also suspected as a carrier in the vicinity of Aden (Covell, 1931).

The species is notorious as the causative agent of regional malaria epidemics of great severity and wide rage. It is well known as an efficient vector of *P. vivax* and *P. falciparum* infections in nature. Siddons (1944) proved by experimental transmissions that the species can be efficient carrier of *P. malariae* infections as well. The work of Russel Menon and Rao at Pattukottai (1938) also shows that the species is responsible for the transmission of all three species of plasmodia.

Senior White (1940) has reviewed the dissection records of this species in different localities in India to show the distribution of its vectorial status. Subsequently more areas have been surveyed and information available is presented below in a tabular form.

TABLE II

Dissections records of A. culicifacies

| Serial No | Author and year | Local ty | Dissect on period | Number dissec- ted | | | | Sporo- zoite | | Oocyst | | Remarks |
|-----------|---------------------------|-----------|---------------------|-----------------------|---|-----|-----|-----------------|---------------|---------------|---------------|---------|
| | | | | 3 | 4 | 5 | 6 | rate per cent | rate per cent | rate per cent | rate per cent | |
| 1 | | | | | | | | | | | | 8 |
| 1 | Cornwall | (1902) | Ennore | | | 25 | 160 | | | 00 | | |
| 2 | Stephens and Christophers | (1942) | Mian Mir (Pakistan) | Oct | | 252 | 40 | | | 00 | | |
| 3 | <i>Idem</i> | (1902) | Ennore | | | 69 | 86 | | | 00 | | |
| 4 | Graham | (1910) | Kosi (Indus) | Oct | | 134 | 15 | | | 13 | | |
| 5 | <i>Idem</i> | (1910) | Kairana | Sept Oct | | 128 | 00 | | | 13 | | |
| 6 | Ross | (1912) | Ennore | Feb May | | 85 | 12 | | | 00 | | |
| 7 | James and Guna sekara | (1913) | Tala mannar | April | | 36 | 21 | | | 00 | | |
| 8 | Graham | (1913) | <i>Meerut</i> | Octo Nov | | 211 | 00 | | | 05 | | |
| 9 | Ross | (1913) | Cuddapah | July Dec | | 200 | 00 | | | 10 | | |
| 10 | Horne | (1914) | Penukonda | Nov Dec | | 16 | 63 | | | 00 | | |
| 11 | Hodgson | (1914 15) | Delhi | Probably July Aug Sep | | | | | | | | |
| 12 | Mhaskar | (1915) | N Kanara | Jan Dec | | 110 | 00 | | | 27 | | |
| 13 | Rao | (1915) | Hospet | Nov Dec | | 837 | 02 | | | 07 | | |
| 14 | <i>Idem</i> | (915) | Ramnad | Jan Feb | | 116 | 17 | | | 00 | | |
| | | | | | | 44 | 00 | | | 45 | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|------------------------|--------|-------------------------------|------------------|------|----|--------------------------------------|
| | | | | | | | Positive found only in September. |
| 15 | Sinton | (1917) | Kohat | July-Sep. | 40 | 00 | 25 |
| 16 | Krishnan | (1925) | Vizagapatam | Nov | 31 | 00 | 33 |
| 17 | Sinton | (1925) | Mani Mayra | June | 6 | 00 | 166 |
| 18. | Ayer | (1925) | Sappal Hill | Apr - May | 98 | 10 | 00 |
| 19 | Feegrade | (1927) | Hsipaw (Assam- Burma) | June-Oct. | 113 | 00 | 08 |
| 20. | Ayer | (1927) | Bimlipatam | Sep. | 37 | 00 | 103 |
| 21. | Mayne | (1927) | Saharanpur | Apr - Sep | 2021 | 01 | 01 |
| 22. | Gale | (1928) | Mawlaik (Burma) | June-Sep | 32 | 00 | 31 |
| 23. | Carter and Jacobs | (1929) | Chilow (Ceylon) | Dec - Jan. | 336 | 65 | 15 |
| 24 | Idem. | (1929) | Karande (Ceylon) | July | 267 | 97 | 64 |
| 25. | King and Krish- nan | (1929) | Udayagiri | Apr. | 42 | 24 | 95 |
| 26. | Venkataraman | (1929) | Vizagapatam | Aug. | 186 | 00 | 16 |
| 27 | Carter and Jacobs | (1929) | Ridigama (Ceylon) | Nov. | 558 | 09 | 22 |
| 28. | Baily | (1929) | Shikarpur (Pakistan) | Aug - Oct - Nov. | 52 | 19 | 115 |
| 29. | Covell and Baily | (1929) | Sukkur (Pakistan) | Sep | 74 | 54 | 95 |
| 30. | Rao | (1929) | Nandyal | Jan - Feb | 68 | 15 | 15 |
| 31. | King and Iyer | (1929) | Mopad | Now. | 297 | 14 | 61 |
| 32. | Young and Majid | (1930) | Larkana (Pakistan) | Oct - Jan. | 186 | 11 | 05 |
| 33. | Covell and Baily | (1930) | Larkana (Pakistan) | Aug Apr | 785 | 27 | 197 |
| 34. | Carter | (1930) | Chilaw (Ceylon) | 25 months | 2294 | 26 | 12 |
| 35 | Feegrade | (1930) | Purinbyu (Doonars Salween) | July-Oct | 41 | 00 | 22 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----|--------------------------|--------|--------------------|---------------------------------|------|-------|--|
| 36 | Freegrade | (1930) | Mazli (Burma) | July Oct | 271 | 38 | 11 |
| 37 | Sweet and Rao | (1931) | Kohr (Mysore) | June | 4 | 500 | 00 |
| 38 | Idem | (1931) | Mysore State | Oct 1928 Dec-1930 | 5635 | 0 124 | 0018 |
| | | | | | | | Epidemic The epidemic in- fection index was 31.25 per cent in 16 dissections |
| 39 | Idem | (1931) | Mysore City | Aug 1930 | 10 | 100 | 00 |
| 40 | Covell and Bailey | (1932) | N. Sind (Pakistan) | | 649 | 118 | 192 |
| 41 | Nursing Sweet and Rao | (1934) | Nagenhalli | Mar Apr 1933 | 271 | 00 | 15 |
| 42 | Idem | (1934) | Hariyur | Nov Dec 1932 33 Oct Nov 1932 | 447 | 044 | 36 |
| 43 | Idem | (1934) | Mandya | Apr-Aug Sep 1933 | 1151 | 10 | 23 |
| | | | | | | | Transmission Mar to June Transmission Nov Dec Epidemic Trans- mission through- out the year Mar during two peri- ods 112 Mar June & Oct Dec Highest sporozoite rate was 13.7% in Nov 1929 dur- ing and epidemic |
| 44 | Covell and Bailey | (1934) | Larkana (Sind) | Aug 1928 Apr 1933 | 6905 | 2 475 | |
| 45 | Nursing Sweet and Rao | (1934) | Mysore | 1932 33 | 1964 | 0 714 | 2 34 |
| 46 | Freegrade | (1934) | Maymyo (Burma) | July Aug | 206 | 00 | 05 |
| 47 | Iyengar | (1934) | Kulasekaram | Feb Sep | 984 | 0 202 | 00 |
| | | | | | | | Inclusive of epide- mic areas |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----|-------------------------|--------------------------------------|--------------------|------|------|-------|--|
| | | | Aug-Sep | | 3 8 | 7 5 | Transmission July-Oct |
| 48. | Ahuja | (1934) Ajmer | | 53 | | | |
| 49 | Covell Baily and Prasad | (1935) Sind | Aug-Dec 1930-33 | 5815 | 1 59 | 2 59 | |
| 50 | Bierchiffe | (1935) Maha oya Basin (Ceylon) | Nov-May | 2482 | 4 7 | 3 8 | Epidemic |
| 51 | Idem | Mahawabi G Basin (Ceylon) | Nov-May | 399 | 2 5 | 4 0 | |
| 52. | Idem | (1935) Deduran oya Bain (Ceylon) | Nov-May | 966 | 3 2 | 2 1 | Epidemic Epidemic. |
| 53 | Mulligun and Baily | (1936) Quetta (Pakistan) | July Oct | 835 | 3 23 | 2 99 | Transmission July-Oct |
| 54 | Viswanathan | (1936) Madakasira | April 1934 | 70 | 2 8 | 2 8 | Epidemic year Transmission throughout the year with peaks in Apr and Nov |
| 55 | Lamprell | (1936) Lumding (Assam) | June Aug | 516 | ■ 8 | 0 0 | |
| 56 | Senior White | (1937) Chatikona (Orissa) | Oct '05 Sep '36 | 1168 | 0 0 | 0 2 | 1st Sept-Dec |
| 57. | Senior White | (1937) Jeypore Hills | Oct '35-Sep '36 | 4744 | 0 0 | 0 06 | |
| 58 | Hicks and Majid | (1937) Karnal Punjab | July '931 Jan 1936 | 8850 | ■ 6 | 0 227 | Transmission July-Nov Max during Aug-Sept |
| 59 | Sweet | (1937) T Narsipur (Mysore) | June 1931-Jan 1936 | 1191 | 0 7 | 3 8 | |
| 60 | Niogi and Khan | (1938) Syllee (Dooar) N Bengal | 6 years | 124 | 0 8 | 0 0 | No epidemic known in this area |
| 61 | Senior White | (1937) Lanygarh Road (Jeypore Hills) | Oct 1936 Sep 1937 | 1067 | 0 00 | 0 09 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----|----------------------|----------|-------------------------------|---------------------|-------|-------|------------------------------------|
| 62 | Ramsay | (1937) | Dharbanga | 16 months | 2988 | 0 07 | 0 07 |
| 63 | Russell et al | (1938) | Pattukkottai | 18 months | 6483 | 0 08 | 0 07 |
| 64 | Barber and Rice | (1938) | Poona | Mar-July 1937 | 874 | 0 4 | 0 0 |
| 65 | Senior White and Das | (1938) | Singhbhum Hills | 1935-1938 | 1611 | 0 0 | 0 31 |
| 66 | Covell et al | (1938) | Delhi | July Oct 1937 | 1028 | 0 097 | 0 097 |
| 67 | Senior White | (1938) | Jeyore Hills | Oct 1936 Sep 1937 | 2446 | 0 0 | 0 082 |
| 68 | Ramsay | (1938) | Peermade | 31 months | 401 | 2 0 | 3 5 |
| 69 | Russell and Jacob | (1939 a) | Ennore | May 1936 June 1938 | 984 | 0 1 | 0 7 |
| 70 | Sundaresan | (1939) | Baruva (Orissa) | Aug to Dec | 122 | 0 0 | 0 8 |
| 71 | Mathew | (1939) | Travancore | Aug 37 to Aug 38 | 1131 | 0 3 | 0 5 |
| 72 | Russell and Rao | (1940-a) | Pattukkottai | Nov 1936 Jan '40 | 13145 | 0 061 | 0 073 |
| 73 | Senior White | (1940) | Chota Nagpur ranges | 1937 1940 | 7482 | 0 0 | 0 2 |
| 74 | Idem | (1940) | Kesinga (Orissa) | June Dec 1936 | 129 | 0 0 | 0 3 |
| 75 | Idem | (1940) | Khodra (Satpura Ranges) | 1938 39 | 700 | 0 0 | 0 1 |
| 76 | Idem | (1940) | Khongsara (Satpura Ranges) | 1938-39 (26 months) | 1317 | 0 0 | 0 15 |
| 77 | Idem | (1940) | Balghara | 1938-39 (1 year) | 541 | 0 0 | 0 1 |
| 78 | Idem | (1940) | Bhadrak (Orissa) | 1931-40 (31 months) | 119 | 0 0 | 0 8 |
| 79 | Idem | (1940) | Paniyazoba | July 1936-Dec 1937 | 425 | 0 0 | 0 2 |
| 80 | Idem | (1940) | Bhanwar Tonk (Satpura Ranges) | 1938 39 (1 year) | 426 | 0 2 | 0 2 |
| 81 | Viswanathan | (1941) | Lumding (Assam) | 1931 1940 | 1232 | 0 4 | 0 16 |
| | | | | | | | Active transmission March November |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----|-------------------------------------|---|--------------------|-------|-------|-------|-------------------------------|
| 82 | Rao and Biswas (1942) | Dharampur Garh (M P) | Aug to Nov 1941 | 969 | 0 5 | 0 0 | |
| 83 | Senior White (1943) and Venkata Rao | Vizagapatam | 1940 1943 | 6608 | 0 015 | 0 05 | |
| 84 | Covell and (1943) Jaswant Singh | Delhi | July Nov 1942 | 9628 | 0 2 | 0 2 | Epidemic |
| 85 | De Burca (1946) | Jubbulpore | Feb Sep 1943 | | | | |
| 86 | Idem (1946) | Mhow | August 1944 | 166 | 2 4 | 2 4 | |
| 87 | Senior White (1946 a) | Dongargarh | Aug Sep Oct 1943 | 258 | 0 38 | 0 18 | |
| 88 | Raghavan and Krishnan (1949) | (Satpura Ranges) Shrihar kottaliland (Andhra State) | 1937 1944 | 4816 | 0 02 | 0 02 | Transmission season Aug Nov |
| 89 | Subramanian and Gupta (1950) | Dharampur Garh (M P) | Feb Aug 1948 | 54 | 1 8 | 1 8 | |
| 90 | Jacob (1950) | Jammu | June 1949 Dec 1950 | 2277 | | | |
| 91 | Viswanathan (1950) | Thana (Bombay) Ahmadabad Kaira B Japur Poona Nasik | 1948 1949 | 1021 | 0 27 | 0 27 | Transmission Sep July |
| | | | 1947 1948 | 737 | 0 27 | 0 57 | |
| | | | 1947 1948 | 1343 | 0 075 | 0 075 | |
| | | | May June 1944 | 3463 | 0 44 | 0 275 | |
| | | | 1948 1949 | 400 | 0 25 | 0 25 | |
| | | | 1948 1949 | 10057 | 0 01 | 0 01 | |
| | | | 1948 1949 | 2786 | 0 0 | 0 0 | |
| | | | 1954 | 5246 | 0 0 | 0 0 | |
| | | | 1954 | 2202 | 0 0 | 0 0 | |
| 92 | Krishnan (1955) | East Khandesh | | | | | Infected specimen in Sep 1954 |
| 93 | Sharma (1955) | Vindhya Pradesh Madhya Bharat | | | | | |

OTHER INFECTIONS

Two specimens of *A. culicifacies* infected with both malaria and filarial infections have been recorded by Russell and Jacob (1939 a) at Ennore. There being no filaria in Ennore it was presumed that labourers (woodcutters) from Sri Harikotta Islands working temporarily at Ennore supplied the source of infection. In Nasik District of Bombay State, Viswanathan (1950) found in a salivary glands preparation of *A. culicifacies* a trypanosome in all stages of development along with plasmodial sporozoites. He gave the name *Trypanosoma kalwarensis* to it. Nematode infections in larvæ as well as adults of *culicifacies* in Ceylon have been recorded by Carter Rustomjee and Saravanamuttu (1927). Sinton (1917) found encysted trematodes in adult *A. culicifacies* at Kohat (Pakistan). This trematode has been named *Agamodistomum sintoni* Van Thiel, 1922. Worms belonging to the genus *Mermis* (Mermithidae) entangled in the malpighian tubules of *A. culicifacies* females have been recorded by Sinton (1932). Micro organisms termed 'pseudosporozoites' belonging to the family Chytridiace of fungi have also been recorded in fresh salivary gland preparations *A. culicifacies* (Bhatia et al., 1953).

CONTROL

The breeding of this species has been very successfully controlled by naturalistic methods like the herbage cover in Madras (Russell and Jacob, 1939 a, Russell and Knipe 1942). With the pyrethrum spray killing, excellent control was obtained against *A. culicifacies* in Delhi (Covell 1941) and in South India (Russell and Knipe 1939, 1940, 1941). The results obtained were particularly good because this species spends most of its time during its gonotrophic cycle indoors and is thus amenable to indoor spraying. Though effective control was obtained by space-spraying once a week, yet Covell and Jaswant Singh (1943) are of opinion that during an epidemic where *A. culicifacies* is the vector, daily spraying will have to be resorted to, to get very effective results. Senior White (1945) comparing the relative efficacy of DDT and pyrethrum against *A. culicifacies* came to the conclusion that DDT residual spray brought down 81 per cent reduction in *A. culicifacies* while pyrethrum space spray twice a week could bring it down to only 49 per cent. With the country-wide use of residual insecticides *A. culicifacies* has been controlled to a very great extent, and malaria in such treated areas will soon cease to be a major public health problem (Rao, 1948, Viswanathan, 1950, Jawant Singh et al., 1951).

REFERENCES

- Afridi, M K, Majid S A (1938) *J Mal Inst Ind*, 1, p 18~
and Jaswant Singh
- Afridi, M K, Jaswant Singh and Harwant Singh (1938) *J Mal Inst Ind*, 2, p 219
- Afridi, M K, Majid, S A (1940) *J Mal Inst Ind*, 3, p 23
and Shah, I A
- Afridi, M K and Puri I M (1940) *Ibid*, 3, p 1
- Ahuja, S. D (1934) *Malaria Survey of Ajmer* Job Press Ajmer
- Aryaratnam, V (1955) *Ind J Mal* 9, p 545
- Ayar, M K. R (1925) Unpublished work reported by Senior White, 1940
- Idem* (1927) *Ibid*
- Baily J D (1929) Unpublished work reported by Senior White 1940
- Barber, M A and Rice, J B (1938) *J Mal Inst Ind* 2 p 37
- Bates M (1940) *Am J Trop. Med*, 20 p 569
- Bhatia, M L (1955) *Bull Nat Soc Ind Mal Mosq Dis*, 3 p 170
- Bhatia M L, Krishnan K S, Mammen M L and Ramakrishnan, S P (1953) *Ibid* 1, p 178
- Bose, K. (1934) *Rec Mal Surv Ind* 2 p 37
- Briercliffe, R (1935) Govt Press, Ceylon
- Brooke Worth, C (1953) *Ind J Mal*, 7, p 125
- Carter H F (1930) *Cey Sci Med*, 2 p 1-1
- Carter H F, Rustomjee K J and Sarvanamuttu E T (1927) Ceylon Sessional paper No VII p 35
- Carter H F and Jacocks, W (1929) *Ceylon J Sci Med*, 2 p 79
- Chalam, B B (1924) *Ind Med Gaz*, 59 p 481
- Christophers S R (1904) *Sci Mem Govt Ind* B Central Govt Press Calcutta
- Idem* (1916) *Ind J Med Res*, 3, p 463
- Idem* (1924) *Ibid*, 12 219
- Idem* (1933) *The Fauna of British India Culicidae* Taylor and Francis London
- Clemeshaw, W W (1927) *Ear Eastern Asian Trop Med Trans of the 7th Congress Brit Ind* 2, p 599
- Idem* (1934) *Cey J Sc D*, 3 p 857
- Clyde D (1931) *Rec Mal Surv Ind*, 2, p 49
- Cornwall J W (1902) *Trans South Ind Brit Med Assoc*, 10 p 5
- Covel, G (1931) *Rec Mal Surv Ind*, 2, p 1
- Idem* (1939) *J Mal Inst Ind*, 2, p 1
- Idem* (1941) *Ibid*, 4, p 1
- Covell, G and Baily, J D (1929) *Rec Mal Surv Ind*, 3, p 310
- Idem* (1930) *Ibid*, 1, p 549
- Idem* (1932) *Ibid* 3 p 279
- Idem* (1934) *Ibid*, 4, p 191

X A culicifacies Giles 1901

- Covel G Baly J D and (1935) *Rec Mal Surv Ind* 5 p 131
- Prasad V
- Well G and Jasant Singh (1943) *J Mal Instt Ind* 5 p 87
- Well and Mulligan H W (1938) *Ib d* 1 p 105
- and Alfred M K
- Navy M L
- DeBures B
- Dew P R
- Fe grade III S.
- Idem
- Idem
- Gale N Maung
- Garewal R S
- Ga chen H
- Gil, C. A.
- Idem
- Giles, G M
- Gisham J D
- Idem
- Idem
- Hicks E P and Majd S A (1937) *Rec Mal Surv Ind* 7 p 267
- Hodgson E C
- Horne J H
- Janger M O T
- Jacob V P
- James, S P
- Jamas S P and Gunasekara (1913) *Govt Press Ceylon*
- S. T.
- James S P and L. ton (1911) *A monograph of the Anopheline mosquitoes of India* p 72 Tacker Spink & Co Calcutta
- W G
- Jasant Singh and Jacob (1944) *J Mal Instt* 3 p 267
- V P
- Jasant Singh and Mohan (1951) *Ind J Mal* 5 p 513
- B N
- (1951) *Ib d* 5 p 235
- Jasant Singh Pal R and Sharma M I D (1929) *Report Eng Ins use Prev Med Gundy* 1923 1928 p 18
- King H H and Krishnan K V (1929) *Sup report Kng Instt* 1927 1928
- Idem (1929) *Supp Rep Kng Inst Gundy* 192 23
- King and Iyer (1935) *Bull Nat Soc Ind Mal Mosq Dis* 3 p 93
- Krishnan K S
- (1925) *Unpublished Reported by Senator White* (1940)
- Krishnan K V
- (1936) *Rec Mal Surv Ind* 6 p 3
- Lamprell B A
- (1935) *Ib d* p 51
- Ludberg K
- (1950) *Anoph Mosq Insq and N Fer a Memo* 7 Lond School Hyg Trop Med p 209
- Maran T T

- Macdonald G and Majid S A (1931) *Rec Mal Surv Ind* 2 p 43
- Majid M A (1937) *Ib id* 7 p 105
- Maratha Instt of Inda (1954) *Report of Malaria Instt of Inda 1948-50*
Govt of India Press
- Mathew M I (1939) *J Mal Instt Ind* 2 p 10
- Mayne M (1927) *Ind J Med Res* ■ p 1073
- Idem* (1930) *Ib id* 17 p 119
- Mehta D R (1934) *Mal Surv Ind* 4 p 41
- Mhaskar K S (1915) *Unpublished Reported by Sen or White 1940*
- Mulgan H W and Dally J D (1936) *Rec Mal Surv Ind* 6 p 289
- Nog S K and Khan B M (1937) *Ib id* 7 p 218
- Nursing D Rao B A and Sweet W C (1934) *Ib id* 4 p 243
- Pal R (1943) *J Mal Instt Ind* 5 p 77
- Idem* (1945) *Ib id* 6 p 239
- Jaem (1845a) *Ib id* 6 p 53
- Idem* (1945b) *Ib id* 6 p 217
- Pal R and Sharma M I D (1952) *Ind J Mal* 6 p 281
- Perry E L (1914) *Ind J Med Res* 2 p 456
- Rafi S M (1955) *Pak J Hlth* ■ p 146
- Raghavan NGS and Irshnan K S (1949) *Ind J Mal* 3 p 9
- Rajendram S Abdul Cader (1950) *Nature* 166 p 486
- M H M and Vavalngam T
- Ramsay G C (1937) *Unpublished Reported by Sen or White 1940*
- Idem* (1938) *Ib id*
- Ramsay G C Chandra S M and Lamprell B A (1936) *Rec Mal Surv Ind* 6 p 49
- Ramsay G C and MacDonald G (1936) *Ind Med Ga* 71 ■ 699
- Rao B A (1948) *Ind J Mal* 2 p 285
- Rao K M (1929) *Govt Press Madras*
- Rao M B and Ramoo M (1942) *J Mal Instt Ind* 4 p 409
- Rao V S (1915) *Govt Press Madras*
- Rao Venka V (1947) *Ind J Mal* 1 p 43
- Ras T E (1912) *Govt Press Madras*
- Idem* (1913) *Ib id*
- Roubaud A (1921) *Bull Soc Path Exot* 14 p 577
- Roubaud A Toussanoff C and Gasched H (1933) *Ib id* 26 p 282
- Roy M N and Bawa TC (1942) *J Mal Instt Ind* 4 p 417
- Russell P E and Jacob V P (1939a) *Ib id* 2 p 131
- Idem* (1939b) *Ib id* 2 and 3 ■ 293
- Idem* (1939c) *Ib id* 2 and 3 ■ 273
- Russell P F and Knipe F W (1939) *Ib id* 2 p 229
- Idem* (1940) *Ib id* 3 p 531

- Idem (1941) *Ibid*, 4 p 181
- Idem (1942) *Ibid*, 4 p 615
- Rusac I M F, Kope F W, Rao, T M and Putnam, P (1944) *J Exp Zool*, 97, p. 135
- Russell P F, Menon M K. and Rao, I R (1938) *J Mal Inst Ind*, 1, p 285
- Russell P F and Rao, T R (1940) *Ibid*, 3, p 153
- Idem (1940) *Ibid*, 3, p 543
- Idem (1940a) *Ibid*, 4, p 263
- Idem (1941) *Amer J Trop Med*, 22 ■ 535
- Idem (1942) *J Exp. Zool* 91, p 303
- Idem (1942a) *Bull Ent Res*, 32, p 341
- Idem (1942b) *Amer J Trop Med*, 22 p 417
- Idem (1942c) *Ibid*, p 535
- Idem (1942d) *Ibid*, p 517
- Senior White R A (1937) *Rec Mal Surv Ind*, 7, p 47.
- Idem (1937a) *Ibid*, 7, p 155
- Idem (1938) *J Mal Inst Ind*, 1, p 129
- Idem (1940) *Ibid*, 3 p 363
- Idem (1945) *Ibid*, 6, p 83
- Idem (1946) *Ibid*, 6, p 425
- Idem (1946a) *Ibid*, 6 p 469
- Idem (1947) *Ind J Mal*, 1 p 211
- Senior White R A and Das B K (1938) *J Mal Inst Ind*, 1 p 169
- Senior White R A Ghosh A R and Venkat Rao V (1945) *Ibid*, 6 p 129
- Senior White, R A and Venkat Rao T (1943) *J Mal Ind*, 5, p 187.
- Sharma, M I D (1945) *Bull Nat Soc Ind Mal Mosq Dis*, 3, p 68
- Sheldon L B (1944) *J Mal Inst Ind* 5, p 375
- Stanton, J A (1917) *Ind J Med Res* 5, p 195
- Idem (1925) *Mos Malaria Inst of India*
- Idem (1932) *Rec Mal Surv Ind*, 3 p 347
- Stephens J W W and Christophers R K. (1902) *Report Mal Committee, Royal Society Series* 7, p 15 Harrison & Sons Ltd
- Subramanian R and Sen Gupta R K. (1950) *Ind J Mol* 4, p 91
- Sundaresan B (1939) Unpublished Reported by Senior White 1940
- Sweet W C. (1937) *Rec Mal Surv Ind*, 7, p 204
- Sweet W C. and Rao, B A (1931) *Ibid*, 2, p 6 6
- Thomson R C M (1940) *J Mal Inst Ind* 3 p 323
- Theobald F V (1903) *A monograph of the culicidae of the World* Brit Mus Nat Hist Cromwell Road, London
- Timber H G (1933) *Rec Mal Surv Ind*, 5, p 145
- Van Thiel (1912) *Tijdschr Vergljk Geneesk*, 7, p 30.
- Velastaraman K V. (1929) *Supp Report King Inst Canady* (1927 28)

- Venkat Rao V (1947) *Ind J Mal*, 1 ■ 43
- Viswanathan, D K (1936) *Rec Mal Surv Ind*, 6 ■ 256
- Viswanathan, D K (1941) *Rep Assocn Med Res Soc Shillong* (1931-1941)
- Idem* (1950) *Malaria in Bombay State* Chittrashala Press 1026 Sadashivpet, Poona
- Viswanathan, D K and Gadre, S. B (1950) *J. Ind Mal* 4, ■ 487,
- Young T C and Majid S A (1930) *Res Mal Surv Ind*, 1, p 391

DISSECTION RECORDS OF WILD CAUGHT
ANOPHELINE MOSQUITOES OTHER THAN
THE REPUTED VECTORS OF MALARIA

BY

B. L. WATTAL

(*Malaria Institute of India, Delhi*)

[May 10, 1957]

APART from the principal vectors of malaria in different parts of the country, one often needs to know the malaria transmission potentialities of other anophelines encountered in a given area. In order to fulfil this requirement all available information on the dissection results of *anophelines* by different workers is summarised specieswise in a tabular form hereunder. Data shown in the Table are according to periods of study. Figures for earlier periods are at the top followed by those of later in a descending order.

Legends: G—Gut
 Gl—Gland

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------|---|-----------------------|------|-----|-------|----|-----|-----------------------|
| Jeypore Hills | | Senior White 1938 | 9 | 0/0 | 0/0 | 0 | 00 | |
| Oct 1936-37 | | | | | | | | |
| Hazar, Bagh | | Senior White 943 | 11 | 0/0 | 0/0 | 0 | 00 | |
| 1936-1943 | | | | | | | | |
| Bengal Nov 1937-38 | | Iyengar 1939 | 894 | 0/0 | 0/0 | 0 | 00 | |
| Bally Calcutta | | Roy 1939 | 9 | 0/0 | 0/0 | 0 | 00 | |
| Aug 1937 July 1938 | | | | | | | | |
| Chitka Lake April | | Senior White 1939 | 481 | 1/0 | *02/0 | *1 | 02* | *Calculated figures 1 |
| 1937 Mar 1938 | | and Adhikari | | | | | | |
| Jeypore Hills | | Senior White 1937 | 107 | 1/0 | *09/0 | *1 | *09 | *Calculated figures |
| Wynaad 1938-39 | | Covell and 1939 | 2940 | 0/0 | 0/0 | 0 | 00 | |
| | | Harbhagwan | | | | | | |
| Darjeeling | | Gutroy 1939 | 33 | 0/0 | 0/0 | 0 | 00 | |
| June Nov 1938 | | | | | | | | |
| Singbhum Hills | | Senior White 1940 | 7 | 0/0 | 0/0 | 0 | 00 | |
| May 1938-Apr 1940 | | and Narayana | | | | | | |
| Coastal Orissa | | Covell and Singh 1942 | 674 | 0/0 | 0/0 | 0 | 00 | |
| Apr 1939-Mar 1942 | | | | | | | | |
| Bengal 1939 | | Iyengar 1940 | 1494 | 0/0 | 0/0 | 0 | 00 | |
| Deltaic Bengal | | Idem 1944 | 1339 | 00 | 0/0 | 0 | 00 | |
| 1939-41 | | | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------------------|------------------------------------|-----|-----|--------|----|------|---------------------|
| Nizamabad 1940-42 | Abraham and 1944 Samuels | 148 | 0/0 | 0/0 | 0 | 00 | |
| Nilgiris Feb. 1940 | Russell and 1942 Jacob | 2 | 0/0 | 0/0 | 0 | 00 | |
| Assam 1940-41 | Vishwanathan 1941 <i>et al.</i> | 254 | 1/0 | 0 4/0 | *1 | *0 4 | *Calculated figures |
| Waltair Sept., 1940 | Senior White 1943 and Rao | 35 | 0/0 | 0/0 | 0 | 00 | |
| Dec. 1941 | Khan 1942 | 44 | 0/0 | 0/0 | 0 | 00 | |
| Darjeeling 1941 | Roy and Biswas 1942 | 1 | 0/0 | 0/0 | 0 | 00 | |
| Udaipur, M P. | | | | | | | |
| Aug-Nov 1941 | | | | | | | |
| Madras 1942-44 | Roy <i>et al.</i> 1946 | 10 | 0/0 | 0/0 | 0 | 00 | |
| Jeypore Hills | Senior White 1945 <i>et al.</i> | 68 | 1/0 | *1 5/0 | *1 | *1 5 | *Calculated figures |
| Mar., 1942-Feb 1943 | Senior White 1947 <i>et al.</i> | 219 | 0/0 | 0/0 | 0 | 00 | |
| Madras Orissa, Coast, Mar 1943 | | | | | | | |
| Dec 1945 | | | | | | | |
| East Central India | Senior White 1946 | 12 | 0/0 | 0/0 | 0 | 00 | |
| 1944-45 | | | | | | | |
| Bissamcuttack | Senior White 1946 and Ghosh | 103 | 0/0 | 0/0 | 0 | 00 | |
| Area 1944 46 | Jafar and 1947 Iyenger | 172 | 0/0 | 0/0 | 0 | 00 | |
| Damodar-Hoogly River Basin | | | | | | | |

| I | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------------------|---|------|-----|-----|---|-----|---|
| | ■ <i>Anopheles Authenti</i> , James 1903 | | | | | | |
| Cachar Assam Apr 1927-Mar 1930 | Ramsay 1930 | 6 | o/o | o/o | ■ | o o | |
| Cachar Apr-Dec 1927 | Strickland 1929 | 3 | o/o | o/o | o | o o | |
| | 3 <i>Anopheles Annandalei</i> , Bains Prashad 1918 | | | | | | |
| | No record of dissections available | | | | | | |
| | 4 <i>Anopheles Annularis</i> , Van der Wulp, 1884 | | | | | | |
| | Vector species | | | | | | |
| | 5 <i>Anopheles Barbrostris</i> , Van der Wulp, 1884 | | | | | | |
| Bengal | Stephens and Christophers 1902 | 2 | o/o | o/o | o | o o | |
| Bengal | Fry 1914 | 23 | o/o | o/o | ■ | o o | |
| Cachar, Assam Apr Dec 1927 | Strickland 1929 | 2 | o/o | o/o | ■ | o o | |
| Mysore | Sweet 1929-30 | 26 | o/o | o/o | o | o o | |
| Cachar Apr 1927 Mar 1930 | Ramsay 1930 | 26 | o/o | o/o | o | o o | |
| Assam | Manson 1931 | 11 | o/o | o/o | o | o o | |
| Bengal 1933-40 | Sen | 1948 | o/o | o/o | o | o o | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------|-------------------|------|-----|-----|---|---|---|
| Tanjore-Madras | Russell and Rao | 1940 | 21 | 0/0 | 0 | 0 | 0 |
| Nov 1936 Jan 1940 | | | | | | | |
| Bengal Nov 1937 38 | Iyengar | 12 | 0/0 | 0/0 | 0 | 0 | 0 |
| S Travancore | Mathew 1939 | 1 | 0/0 | 0/0 | 0 | 0 | 0 |
| Aug 1937 38 | | | | | | | |
| Bally Calcutta | Roy 1939 | 43 | 0/0 | 0/0 | 0 | 0 | 0 |
| Aug 1937 July 1938 | | | | | | | |
| Ennore Nellore | Russell and 1939 | 22 | 0/0 | 0/0 | 0 | 0 | 0 |
| May 1937 June 1938 | Jacob | | | | | | |
| Chilka Lake | Senior White 1939 | 3 | 0/0 | 0/0 | 0 | 0 | 0 |
| Apr 1937-Mar 1938 | and Adhikari | | | | | | |
| Wynaad 1938 39 | Covell and 1939 | 19 | 0/0 | 0/0 | 0 | 0 | 0 |
| | Harbhagwan | | | | | | |
| Jharia Bihar | Rao 1941 | 8 | 0/0 | 0/0 | 0 | 0 | 0 |
| Apr 1938 Sept 1940 | | | | | | | |
| Bengal, 1939 | Iyengar 1940 | 44 | 0/0 | 0/0 | 0 | 0 | 0 |
| Deltaic Bengal | Idem 1944 | 49 | 0/0 | 0/0 | 0 | 0 | 0 |
| 1939 41 | | | | | | | |
| Nalgiris Feb 1940 | Russell and | 1 | 0/0 | 0/0 | 0 | 0 | 0 |
| Jan 1941 | Jacob 1942 | | | | | | |
| Assam 1940 41 | Vishwanathan | 89 | 0/0 | 0/0 | 0 | 0 | 0 |
| | et al 1941 | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|--|------|-----|-----|---|-----|---|
| | 10. <i>Anopheles Gigas</i> , Giles 1901 | | | | | | |
| Assam 1940-41. | Vishwanathan et al. 1941 | 18 | 0/0 | 0/0 | ■ | 0 0 | |
| Nilgiris Feb 1940- Jan 1941 | Russell and Jacob 1942 | 5 | 0/0 | 0/0 | 0 | 0 0 | |
| | 11. <i>Anopheles Hyrcanus</i> var <i>Nigerrimus</i> Giles 1900 | | | | | | |
| Calcutta | Stephens and Christophers 1902 (a) | 8 | 0/0 | 0/0 | 0 | 0 0 | |
| Meerut | Graham 1911 | 22 | 0/0 | 0/0 | 0 | 0 0 | |
| Bengal | Fry, 1914 | 66 | 0/0 | 0/0 | 0 | 0 0 | |
| Kanara | Mhaaskar* 1914 | 7 | 0/0 | 0/0 | 0 | 0 0 | |
| Krishnagar Bengal | Sur and Sur 1929 | 190 | 0/0 | 0/0 | 0 | 0 0 | |
| Burnager Bengal | Idem 1929 | 74 | 0/0 | 0/0 | 0 | 0 0 | |
| Cachar Assam | Strickland 1929 | 1757 | 0/0 | 0/0 | 0 | 0 0 | |
| Apr-Dec. 1927 | | | | | | | |
| Cachar Apr. 1927- Mar. 1930 | Ramsay, 1930 | 5461 | 0/0 | 0/0 | ■ | 0 0 | |
| Jorhat Assam | Idem 1931 | 209 | 0/0 | 0/0 | 0 | 0 0 | |
| W. Bengal 1933-40 | Sen, 1948 | 610 | 0/0 | 0/0 | 0 | 0 0 | |
| Tanjore : Madras Nov 1936-Jan. 1940 | Russell and Rao 1940 | 436 | 0/0 | 0/0 | 0 | 0 0 | |
| S. Travancore | Mathew 1939 | 3 | 0/0 | 0/0 | 0 | 0 0 | |

*Reported by Covell
1927

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|------------------------------------|------|-----|-----|---|-----|---|
| 10 <i>Anopheles Gigas</i> , Giles 1901 | | | | | | | |
| Assam 1940-41 | Vishwanathan <i>et al</i> 1941 | 18 | o/o | o/o | ■ | o o | |
| Nilgiris Feb 1940 | Russell and Jacob 1942 | 5 | o/o | o/o | o | o o | |
| Jan 1941 | | | | | | | |
| 11 <i>Anopheles Hyrcanus</i> var <i>Nigerrimus</i> Giles 1900 | | | | | | | |
| Calcutta | Stephens and Christophers 1902 (a) | 8 | o/o | o/o | o | o o | |
| Meerut | Graham 1911 | 22 | o/o | o/o | o | o o | |
| Bengal | Fry, 1914 | 66 | o/o | o o | o | o o | |
| Kanara | Mhaskar* 1914 | 7 | o/o | o/o | o | o o | |
| Krishnagar Bengal | Sur and bur 1929 | 190 | o/o | o/o | o | o o | |
| Birnager Bengal | <i>Idem</i> 1929 | 74 | o/o | o/o | o | o o | |
| Cachar Assam | Strickland 1929 | 1757 | o/o | o/o | o | o o | |
| Apr-Dec 1927 | | | | | | | |
| Cachar Apr 1927-Mar 1930 | Ramsay, 1930 | 5461 | o/o | o/o | o | o o | |
| Jorhat Assam | <i>Idem</i> 1931 | 209 | o/o | o/o | o | o o | |
| W Bengal 1933-40 | Sen, 1948 | 610 | o/o | o/o | o | o o | |
| Tanjore - Madras | Russell and Rao 1940 | 436 | o/o | o/o | ■ | o o | |
| Nov 1936-Jan 1940 | | | | | | | |
| S Travancore | Mathew 1939 | ■ | o/o | o/o | o | o o | |

*Reported by Covell 1927

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------|------------------------|-------|-----|-----|---|----|---|
| Aug 1937-38 | | | | | | | |
| Bengal 1937-38 | Iyengar 1939 | 405 | 0/0 | 0/0 | 0 | 00 | |
| Bally Calcutta | Roy 1939 | 129 | 0/0 | 0/0 | 0 | 00 | |
| Aug 1937-38 | | | | | | | |
| Ennore-Nellore | Russell and Jacob 1939 | 9 | 0/0 | 0/0 | 0 | 00 | |
| May 1937-June 1938 | | (2/9) | | | | | |
| Wynad | Covell and 1939 | 90 | 0/0 | 0/0 | ■ | 00 | |
| 1938-39 | Harbhagwan | | | | | | |
| Jharia Bihar | Rao 1941 | 20 | 0/0 | 0/0 | 0 | 00 | |
| April 1938-Sept. 1940 | | | | | | | |
| Bengal 1939 | Iyengar 1940 | 727 | 0/0 | 0/0 | 0 | 00 | |
| Chulka Lake | Senior White | 50 | 0/0 | 0/0 | 0 | 00 | |
| 1939 | and Adhikari 1939 | | | | | | |
| Deltaic Bengal | Iyengar 1944 | 480 | 0/0 | 0/0 | ■ | 00 | |
| 1939-41 | | | | | | | |
| Assam 1940-41 | Vishwanathan | 161 | 0/0 | 0/0 | ■ | 00 | |
| | et al 1941 | | | | | | |
| Nilgiris | Russell and Jacob 1942 | 38 | 0/0 | 0/0 | 0 | 00 | |
| Feb. 1940-Jan. 1941 | | | | | | | |
| Nizamabad | Abraham and | 106 | 0/0 | 0/0 | ■ | 00 | |
| 1940-42 | Samuels 1944 | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|-----------------------------------|-----|-----|-----|---|-----|---|
| Kurnool, Anantpur and Cuddapah 1942-44 | Rao <i>et al</i> 1946 | 138 | 0 0 | 0 0 | 0 | 0 0 | |
| North Kanara May 1942-May 1943 | Singh and Jacob 1944 | 72 | 0/0 | 0/0 | 0 | 0 0 | |
| Damodar Hooghlo Basin | Jafar and Lyengar 1947 | 72 | 0/0 | 0/0 | 0 | 0 0 | |
| Nellore Feb-Aug and Dec 1948 | Raghavan and 1939 Krishnan | 7 | 0/0 | 0/0 | 0 | 0 0 | |
| Udaipur, Raj July-Dec 1949 | Subramanian and Gupta 1950 | 286 | 0/0 | 0/0 | 0 | 0 0 | |
| 12 <i>Anopheles Insulaeflorum</i> , Swell and Swell | | | | | | | |
| No dissection records available | | | | | | | |
| 13 <i>Anopheles Jamesi</i> , Theobald 1901 | | | | | | | |
| Cachar Assam April-Dec 1927 | Strickland 1929 | 8 | 0/0 | 0/0 | 0 | 0 0 | |
| Mysore | Sweet 1929-30 | 216 | 0/0 | 0/0 | 0 | 0 0 | |
| Cachar | Ramsay 1930 | 162 | 0/0 | 0/0 | 0 | 0 0 | |
| Apr 1927-Mar 1930 | | | | | | | |
| Orissa Coastal Plain 1935-41 | Senior White <i>et al</i> 1943 | 20 | 0/0 | 0/0 | 0 | 0 0 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------------|------------------------|--------|-----|-----|---|----|-----------------------------|
| Jeyapore Hills | Senior White 1937 | 2 | 0/0 | 0/0 | 0 | 00 | |
| Tanjore Madras | Russell and Rao 1940 | 305 | 0/0 | 0/0 | 0 | 00 | |
| Nov 1936-Jan 1940 | | | | | | | |
| Satpura Ranges | *Senior White 1940 | 140 | 0/0 | 0/0 | 0 | 00 | *Reported by Kennik 1915 |
| 1936-40 | | 6 | 0/0 | 0/0 | 0 | 00 | |
| Hazaribagh | Idem 1943 | 10 | 0/0 | 0/0 | 0 | 00 | |
| 1936-43 | | | | | | | |
| Ennore Nellore | Russell and Jacob 1939 | 11 | 0/0 | 0/0 | 0 | 00 | |
| May 1937-38 | | (8/10) | | | | | |
| S Travancore | Mathew 1939 | 23 | 0/0 | 0/0 | 0 | 00 | |
| Aug 1937-38 | | | | | | | |
| Bengal Nov 1937-38 | Iyengar 1939 | 3 | 0/0 | 0/0 | 1 | 00 | |
| Wynad Madras | Covell and | 1749 | 00 | 0/0 | 0 | 00 | |
| 1938-39 | Harbhagwan 1939 | | | | | | |
| Singbhum | Senior White and | 1 | 00 | 00 | 0 | 00 | |
| May 1938-April 1940 | Narayana 1940 | | | | | | |
| Darjeeling | Gilroy 1939 | 10 | 00 | 00 | 1 | 00 | |
| June Nov 1938 | | | | | | | |
| Bengal, 1939 | Iyengar 1940 | 3 | 00 | 00 | 0 | 00 | |
| Nilgiri | Russell and Jacob 1942 | 94 | 00 | 00 | 0 | 00 | |
| Feb 1940 Jan 1941 | | | | | | | |
| Walter | Senior White and | 1 | 00 | 00 | 0 | 00 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|-----------------------------------|------|-----|-------|----|-------|---------------------|
| Sept. 1940 Dec 1941 | Rao 1943 | | | | | | |
| Nizamabad 1940-47 | Abraham and Samuels 1944 | 2 | 0/0 | 0/0 | 0 | 0 0 | |
| North Kanara | Singh and Jacob 1945 | 653 | 0/0 | 0/0 | 0 | 0 0 | |
| May 1942-May 1943 | | | | | | | |
| Vector species. | | | | | | | |
| 14. <i>Anopheles Jeyporensis</i> , James 1902 | | | | | | | |
| 15. <i>Anopheles Karnati</i> , James 1903 | | | | | | | |
| Cachar : Assam | Strickland 1929 | 1697 | 1/0 | 05/0* | 1* | ■ 05* | *Calculated figures |
| Apr-Dec. 1927 | | | | | | | |
| Mysore | Sweet 1929-30 | 40 | 0/0 | 0/0 | 0 | 0 0 | |
| Cachar | Ramsay 1930 | 9252 | 0/0 | 0/0 | ■ | 0 0 | |
| Apr. 1927-Mar. 1930 | | | | | | | |
| Coastal Orissa 1935-41 | Senior White et al. 1943 | 1 | 0/0 | 0/0 | ■ | 0 0 | |
| Hazaribagh 1936-43 | Senior White 1943 | 2 | 0/0 | 0/0 | 0 | 0 0 | |
| Sarpura Rang 1936-40 | Senior White and Adhikari 1940 | 2 | 0/0 | 0/0 | ■ | 0 0 | |
| S. Travancore | Mathew 1939 | 5 | 0/0 | 0/0 | ■ | 0 0 | |
| Aug. 1937-Aug. 1938 | | | | | | | |
| Bengal | Iyengar 1939 | 10 | 0/0 | 0/0 | ■ | 0 0 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------------------|---------------------------------------|---|------|------------|-----|------|---------------------|
| | | 18 <i>Anopheles Lindseyi</i> , Giles 1900 | | | | | |
| Darjeeling 1941 | Khan 1942 | 9 | 0/0 | 0/0 | 0 | 0 0 | |
| | | 19 <i>Anopheles Maculatus</i> , Theobald 1901 | | | | | |
| Bengal (Calcutta) | Stephens and Christophers 1902 (a) | 11 | 0/0 | 0/0 | 0 | 0 0 | |
| Assam | Short 1924 | 62 | 0/0 | 0/0 | 0 | 0 0 | |
| Cachar : Assam | Strickland 1929 | 147 | 0/0 | 0/0 | 0 | 0 0 | |
| Apr Dec 1927 | | | | | | | |
| Cachar 1927-30 | Ramsay 1930 | 3374 | 0/0 | 0/0 | 0 | 0 0 | |
| Banbassa U P | Clyde 1931 | 60 | 0/0 | 0/0 | 0 | 0 0 | |
| Assam 1931-41 | Anderson and Vishwanathan 1941 | 8483 | 24/5 | *0 28/0 05 | *29 | *0 3 | *Calculated figures |
| Satpura Ranges 1936 40 | Senior White and Adhikari 1940 | 12 | 0/0 | 0/0 | 0 | 0 0 | |
| Hazaribagh 1936-43 | Senior White 1943 | 22 | 0/0 | 0/0 | 0 | 0 0 | |
| Jeypore Hills | Idem 1937 | 13 | 0/0 | 0/0 | 0 | 0 0 | |
| Bengal | Iyengar 1939 | 69 | 0/0 | 0/0 | 0 | 0 0 | |
| Nov 1937-Nov 1938 | | | | | | | |
| Wynaad 1937-39 | Covell and Harbhagwan 1939 | 1 | 0/0 | 0/0 | 0 | 0 0 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------|---|------|------|---------|-----|----|---------------------|
| Darjeeling | Gilroy 1939 | 11 | o/o | o/o | 0 | 00 | |
| June Nov 1938 | | | | | | | |
| Assam 1940-41 | Vishwanathan <i>et al</i> 1941 | 1573 | 33/1 | *08/006 | *14 | 09 | *Calculated figures |
| Nilgiris | Russel and Jacob 1942 | 39 | o/o | o/o | 0 | 00 | |
| Feb 1940 Jan 1941 | | | | | | | |
| Waltair | Senior White and | 9 | o/o | o/o | 0 | 00 | |
| Sept 1940-Dec 1941 | Rao 1943 | | | | | | |
| Singhbhum Hills | Senior White and | 1 | o/o | o/o | 0 | 00 | |
| May 1938-Apr 1940 | Narayana 1940 | | | | | | |
| Darjeeling 1941 | Khan 1942 | 1725 | c/o | o/o | 0 | 00 | |
| | | 197 | o/o | o/o | 0 | 00 | |
| North Kanara | Singh and 1944 | 3 | o/o | o/o | 0 | 00 | |
| May 1942-May 1943 | Jacob | | | | | | |
| | 2c <i>Anopheles Majidi</i> McCombie Young and Majid, 1928 | | | | | | |
| Darjeeling | Gilroy 1939 | 11 | o/o | o/o | 0 | 00 | |
| June-Nov 1938 | | | | | | | |
| Wynaad | | | | | | | |
| 1938-39 | Covell and 1939 | 72 | o/o | 6/o | 0 | 00 | |
| Nilgiris | Harbhagwan | | | | | | |
| Feb 1940 Jan 1941 | Russell and 1942 | 28 | o/o | o/o | 0 | 00 | |
| | Jacob | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---------------------------------|----------------------|--|------|---------|----|-------|----------------------|
| Vector species | 21 | <i>Anopheles Minimus</i> , Theobald, 1901 | | | | | |
| | 22. | <i>Anopheles Moghylensis</i> , Christophers, 1924* | | | | | |
| | Kennick 1914 | 43 | 0/0 | 0/0 | ■ | 0 0 | |
| | 23 | <i>Anopheles Multiclor</i> , Cambouliu, 1902 | | | | | |
| No dissection records available | 24. | <i>Anopheles Pallidus</i> , Theobald, 1901. | | | | | |
| Krishnagar Bengal | Sur and Sur 1929 | 1232 | †0/3 | *0/0 2 | *3 | *0 2 | *Calculated figures. |
| Birnagar . Bengal | Idem 1929 | 234 | 0/0 | 0/0 | ■ | 0 0 | |
| Mysore | Sweet 1929-30 | 82 | 0/0 | 0/0 | ■ | 0 0 | |
| Birnagar : Bengal | Bose 1931 | 403 | 1/0 | *0 2/0 | *1 | *0 2 | *Calculated figures, |
| W Bengal 1933-40 | Sen 1948 | 28 | 0/0 | 0/0 | 0 | 0 0 | |
| Coastal Orissa | Senior White 1943 | 1409 | 1/0 | *0 07/0 | *1 | *0 07 | *Calculated figures |
| 1935-41 | et al. | 36 | 0/0 | 0/0 | 0 | 0 0 | *Reported by |
| Birbhum | Timbres 1935 | 27238 | 0/9 | *0/0 03 | *9 | *0 03 | Kennick 1915 |
| Birbhum | Iyengar 1939 | 254 | 2/0 | *0 8/2 | *2 | *0 8 | *Calculated figures. |
| Jeypore Hills | Senior White 1938 | 14 | 0/0 | 0/0 | 0 | 0 0 | |
| Oct 1936-Sept 1937 | | | | | | | |
| Tanjore Madras | Russell and Rao 1940 | 108 | 0/0 | 0/0 | 0 | 0 0 | |
| 1936-42 | | | | | | | |

† Erroneously reported as 3 gut infections instead of glands by Covell, 1944 and Horsfall, 1955

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------------------|-----------------------------|---------|------|---------|----|-------|---------------------|
| Satpura Ranges | Senior White 1946 | 3157 | 4/0 | *0 13/0 | *4 | *0 13 | *Calculated figures |
| Jeypore Hills | Senior White 1937 | 68 | 0/0 | 0/0 | 0 | 0 0 | |
| Hazaribagh | Senior White 1943 | 3819 | 0/0 | 0/0 | ■ | 0 0 | |
| 1936 43 | | | | | | | |
| Ennore Nellore | Russell and 1939 | 19 | 0/0 | 0/0 | ■ | 0 0 | |
| May 1937 June 1938 | Jacob | (14/19) | | | | | |
| Bally Calcutta | Roy 1939 | 1 | 0/0 | 0/0 | ■ | 0 0 | |
| Aug 1937 July 1938 | | | | | | | |
| Bengal Nov 1937 38 | Iyengar 1939 | 508 | */20 | 0 5/0* | *2 | 0 5* | *Calculated figures |
| Chikka Lake Apr 1937 | Senior White and | 15 | 0/0 | 0/0 | 0 | 0 0 | |
| Mar 1938 | Adhikas 1939 | | | | | | |
| S ngbbhum Hills 1938 | Senior White 1938 | 322 | 0/0 | 0/0 | 0 | 0 0 | |
| S ngbbhum H l's 1938 | Senior White and | 279 | 0/0 | 0/0 | 0 | 0 0 | |
| 1940 | Narayana 1940 | | | | | | |
| Jheria Bihar | Rao 1941 | 1 | 0/0 | 0/0 | ■ | 0 0 | |
| Apr 1938 Sept 1940 | | | | | | | |
| Bengal 1939 | Iyengar 1940 | 179 | 0/0 | 0/0 | 0 | 3 0 | |
| Deltaic Bengal 1939 41 | Idem 1944 | 71 | 0/0 | 0/0 | ■ | 0 0 | |
| Assam 1940 41 | V Chwanathan et al 1941 | 12 | 0/0 | 0 0 | 0 | 0 0 | |
| Walter Sept 1940 | Sen or White and | | | | | | |
| Dec 1941 | Rao 1943 | 11 | 0 0 | 0/0 | 0 | 0 0 | |
| N zamabed 1940 42 | Abraham and Samuels 1944 | 135 | 0 0 | 0/0 | 0 | 0 0 | |

| 1 | 2 | 3 | 4 | 5 | 6* | 7* | 8 |
|---|-------------------------------|------|--|-------|----|------|---------------------|
| Udaipur, Raj Aug - Nov 1941 | Roy and Biswas 1942 | 854 | 0/6 | 0/0 7 | 6* | 7* | *Calculated figures |
| North Kanara May 1942-43 | Singh and Jacob 1944 | 980 | 0/0 | 0/0 | ■ | 0 0 | |
| Kurnool, Anantapur Cuddapah, 1942-44 | Rao et al 1946 | 132 | 0/0 | 0/0 | 9 | 0 0 | |
| East Central India 1943-45 | Senior White 1946 | 224 | 0/0 | 0/0 | ■ | 0 0 | |
| Damodar-Hoogly Basin | Jafar and Iyengar 1947 | 322 | 0/0 | 0/0 | 0 | 0 0 | |
| Nellore Feb-Aug and Dec 1948 | Raghavan and Krishnan 1949 | 8 | 0/0 | 0/0 | 0 | 0 0 | |
| Udaipur M P July- Dec. 1949 | Subramanian and Gupta 1950 | 7121 | 0/0 | 0/0 | 0 | 0 0 | |
| Vector species | | 25 | <i>Anopheles Philippinensis</i> Ludlow, 1932 | | | | |
| No dissection record available | | 26 | <i>Anopheles Pinyaurensis</i> Barraud, 1932 | | | | |
| | | 27 | <i>Anopheles Pulcherrimus</i> Theobald, 1902 | | | | |
| Ferozepur 1903 | Adie 1905 | 2/8 | 0/0 | 0/0 | ■ | 0 0 | |
| Koti U P | Graham 1810 (a) | 12 | 0/0 | 0/0 | ■ | 0 0 | |
| | DeSouza 1914 | 95 | 0/0 | 0/0 | ■ | 0 0* | *(Covell, 1937) |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------------------|---------------------------|---------------------------------------|-----|---------|----|--------|------------------------------|
| Amritsar, Punjab | Gull 1917 | 5 | 0/0 | 0/0 | ■ | 0 0 | |
| | 28 | <i>Anopheles Ramsayi</i> Covell, 1927 | | | | | |
| Cachar, Assam | Strickland 1929 | 256 | 0/1 | 0/0 4* | 1* | 0 4* | *Calculated figures |
| Apr-Dec 1927 | | | | | | | |
| Assam Apr 1927 | Ramsay 1930 | 287 | 0/1 | 0/0 3* | 1* | 0 4* | *Calculated figures |
| Mar 1930 | | | | | | | |
| Krishnagar Bengal | Sur and Sur 1929 | 123 | 0/0 | 0/0 | 0 | 0 0 | |
| Birnagar | Sur and Sur 1929 | 99 | 0/0 | 0/0 | 0 | 0 0 | |
| Assam 1927-1935 | Ramsay and Macdonald 1936 | 2217* | 4/0 | 0/20 | 4 | 0 2 | *Includes 287 by Ramsay 1930 |
| W Bengal 1933-1940 | Sen 1948 | 140 | 0/0 | 0/0 | 0 | 0 0 | |
| Orissa coastal plain 1935-1941 | Senior White et al 1943 | 556 | 1/0 | 0 18/0* | 1* | 0 0 18 | *Calculated figures |
| Hazaribagh 1936-1943 | Senior White 1943 | 27 | 0/0 | 0/0 | 0 | 0 0 | |
| Chilla lake Apr 1937 | Senior White and | | | | | | |
| Mar 1938 | Adhikari 1939 | 16 | 0/0 | 0/0 | 0 | 0 0 | |
| Bally Calcutta | Roy 1939 | 40 | 0/0 | 0/0 | ■ | 0 0 | |
| Aug 1937-July 1938 | | | | | | | |
| Bengal Nov. 1937-38 | Jyengar 1939 | 524 | 0/0 | 0/0 | 0 | 0 0 | |
| Bengal 1939 | Jyengar 1940 | 952 | 0/0 | 0/0 | 0 | 0 0 | |
| Deltaic Bengal | Jyengar 1944 | 742 | 1/0 | 0 1/0* | 1* | 0 1* | *Calculated figures |
| Puri Apr 1940 | Panigrahi 1942 | 1658 | 1/0 | 0 06/0* | 1* | 0 06* | *Calculated figures |
| March 1941 | | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------------------|--------------------------|--|-----|--------|----|------|---------------------|
| Waltair Sept 1940 | Senior White and | 1 | o/o | o/o | o | o o | |
| Dec 1941 | Rao 1943 | | | | | | |
| E C India 1944 | Senior White 1946 | 1 | o/o | o/o | o | o o | |
| Damodars Hoogly | Jafer and Lyengar 1947 | 31 | o/o | o/o | o | o o | |
| Basin | | | | | | | |
| No dissection record available | | | | | | | |
| | | 29 <i>Anopheles Sintoni</i> Puri 1929 | | | | | |
| | | 30 <i>Anopheles Splendidus</i> Koidzumi 1920 | | | | | |
| Jeypore Hills | Perry 1914 | 12/19 | o/o | o/o | o | o o | |
| March Nov 1912 | | | | | | | |
| Sabaranpur | Mayne 1928 | 258 | o/o | o/o | o | o o | |
| Feb Sept 1937 | | | | | | | |
| Mysore S India | Sweet 1929 39 | 22 | o/o | o o | o | o o | |
| Banbassa U P | Clyde 1931 | 35 | o/o | o/o | ■ | o o | |
| Karnal | Macdonald and Majid 1931 | 26 | 1/0 | *4 o o | *o | *4 o | *Calculated figures |
| Singhbhum Hills | Senior White and | 16 | o/o | o/o | o | o o | |
| Sept 1935 Dec 1937 | Dass 1938 | | | | | | |
| Jeypore Hills | Senior White 1937 | 38 | o/o | o/o | o | o o | |
| Jeypore Hills | Senior White 1938 | ■ | o/o | o/o | o | o c | |
| Oct 1936 37 | | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------------------|---|-----|-----|-----|---|---|---|
| | | | | | | | |
| Eastern Satpura ranges | Senior White and | 56 | o/o | o/o | o | o | |
| 1946 40 | Adhikari 1940 | | | | | | |
| Wynnad 1938-39 | Covell and Harbhagwan | 55 | o/o | o/o | ■ | o | |
| | 1939 | | | | | | |
| Singhbhum Hills | Senior White and | 11 | o/o | o/o | o | o | |
| May 1938-April 1940 | Narayan 1940 | | | | | | |
| Bangal 1939 | Iyengar 1940 | 7 | o/o | o/o | o | o | |
| Assam 1940-41 | Vishwanathan et al 1941 | 8 | o/o | o/o | ■ | o | |
| Nigiris Feb 1940 41 | Russel and Jacob 1942 | 12 | o/o | o/o | ■ | o | |
| Waltair | Senior White and | 1 | o/o | o/o | o | o | |
| Sept 40-Dec 41 | Rao 1933 | | | | | | |
| Jharia Bihar 1941 | Rao 1941 | 6 | o/o | o/o | o | o | |
| Darjeeling 1941 | Khan 1942 | 48 | o/o | o/o | o | o | |
| E C India 1944-45 | Senior White 1946 | 1 | o/o | o/o | o | o | |
| North Kanara 1944 | Singh and Jacob 1944 | 5 | o/o | o/o | o | o | |
| Khandwa M. P | Subramaniam and | 9 | o/o | o/o | ■ | o | |
| July 1948 Dec 1948 | Dixit 1948 | | | | | | |
| Udaipur M P | Subramanian and | 234 | o/o | o/o | o | o | |
| July-Dec 1949 | Gupta 1950 | | | | | | |
| Vector Species | | | | | | | |
| | 31 <i>Anopheles Stephensi</i> Liston 1901 | | | | | | |
| | 32 <i>Anopheles Subpictus</i> Grassi 1899 | | | | | | |
| Mian Mir | James 1902 | 496 | o/o | o/o | ■ | o | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-------------------|--------------------------------------|-------------------|-----|--------|--------|------|------------------------------|
| Ennur | Stephens and christopher 1902 (b) | 364 | 0/0 | 0/0 | 0 | 00 | |
| Perozepur 1903 | Adie 1905 | 1/2 | 00 | 0/0 | 0 | 00 | |
| Kaurana | Graham 1910 (b) | 27 | 0/0 | 0/0 | 0 | 00 | |
| Bombay | Bentley* 1911 | 772 | 0/0 | 0/0 | 0 | 00 | *Reported by covell, 1927 |
| Kanara | Mbasker 1915 | 431 | 0/0 | 0/0 | 0 | 00 | |
| Punjab | Gill 1917 | 142 | 0/0 | 0/0 | 0 | 00 | |
| Delhi | Hodgson 1914 | 84 | 0/0 | 0/0 | 0 | 00 | |
| Bimlipatam Madras | Iyear 1927 | 316 | 0/0 | 0/0 | 0 | 00 | |
| baharanpur | Mayne 1928 | 1650 | 0/0 | 0/0 | 0 | 00 | |
| Feb -Sept 1927 | | | | | | | |
| Udayagiri Madras | Iyear 1929 | 53 | 0/0 | 0/0 | 0 | 00 | |
| Mopad Madras | King H H and Krishnan 1929 (a) | 122 | 0/0 | 0/0 | 0 | 00 | |
| Udayagiri Madras | Idem 1929 (b) | 60 | 0/0 | 0/0 | 0 | 00 | |
| Krishnagar Bengal | Sur and Sur 1929 | 1302 | 0/0 | 0/0 | 0 | 00 | |
| Mysore S India | Sweet 1929 30 | 3935 | 0/0 | 0/0 | 0 | 00 | |
| Lucknow | Banerjee 1930 | 89 | 0/0 | 0/0 | 0 | 00 | |
| April Sept 1929 | | | | | | | |
| Bengal 1933 40 | Sen 1948 | 1564 | 0/0 | 0/0 | 0 | 00 | |
| Tanjore Madras | Russell and 1940 | 13277 | 2/1 | *001/0 | *007/3 | *002 | *Calculated figures |
| Nov 1936 Jan 1940 | Rao | (12360/ 11017) | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------|----------------------|---------|-----|---------|----|-------|---------------------|
| | Barber and Rice 1928 | 135/623 | 0/0 | 0/0 | 0 | 0 0 | |
| Poona | | | | | | | |
| March July 1937 | Iyengar 1939 | 65 | 0/0 | 0/0 | 0 | 0 0 | |
| Bengal Nov 1937-38 | Roy 1929 | 332 | 0/0 | 0/0 | 0 | 0 0 | |
| Bally Calcutta | | | | | | | *Calculated figures |
| Aug 1937 July 1938 | Russell and 1939 | 4897 | 2/1 | *0 05/0 | *2 | *0 04 | |
| Ennore-Nellore | Jacob | 4013/ | | | | | |
| May 1937-June 1938 | | 4893 | | | | | |
| | Soman 1945 | 88 | 0/0 | 0/0 | 0 | 0 0 | |
| Pandharpur Bombay | | | | | | | *Calculated figures |
| Sept 1937 May 1938 | Russell et al 1939 | 8381 | 4/1 | *0 05/ | 5 | *0 06 | |
| Ennore Neller | | 7409/ | | 0 01 | | | |
| Pattukkotta | | 8308 | | | | | |
| | Gilroy 1939 | 1 | 0 0 | 0 0 | | 0 0 | |
| Darjeeling | | | | | | | |
| June-Nov 1938 | Lovell and 1939 | 509 | 0/0 | 0/0 | 0 | 0 0 | |
| Wynaad | Harbhagwan | | | | | | |
| 1938-39 | Rao 1941 | 1625 | 0/0 | 0 0 | 0 | 0 0 | |
| Jharia Bihar | | | | | | | |
| Apr 1938 Sept 1940 | Iyengar 1944 | 576 | 0 0 | 0/0 | 0 | 0 0 | |
| Deltaic Bengal | | | | | | | |
| 1939-41 | Russell and 1942 | 387 | 0 0 | 0/0 | | 0 0 | |
| Nalgiris | Biswas | | | | | | |
| Feb 1940-Jan 1941 | Viswanathan et al | 353 | 0/0 | 0/0 | 0 | 0 0 | |
| Assam 1940 41 | | | | | | | |

| | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|-----------------------------|--|-----|-----|---|-----|---|
| Nizamabad 1940-42 | Abraham and Samuels 1944 | 2323 | 0/0 | 0/0 | 0 | 0 0 | |
| Darjeeling 1941 | Khan 1942 | 24 | 0/0 | 0/0 | ■ | 0 0 | |
| Udaipur M P | Roy and 1942 | 115 | 0/0 | 0/0 | 0 | 0 0 | |
| Aug 1918 Nov 1941 | Biswas | | | | | | |
| North Kanara | Singh and | 806 | 0/0 | 0/0 | 0 | 0 0 | |
| May 1942 May 1943 | Jacob 1944 | | | | | | |
| Kurnool Anantapur & Chaddapah 1942-44 | Rao et al 1946 | 4647 | 0/0 | 0/0 | ■ | 0 0 | |
| Damodar | Jayer and 1947 | 25 | 0/0 | 0/0 | 0 | 0 0 | |
| Hooghly basin | Iyenger | | | | | | |
| Khandwa C P. | Subramanian and 1948 | 30 | 0/0 | 0/0 | 0 | 0 0 | |
| 1948 | Dixit | | | | | | |
| Sri Hasipoth-Nellore | Bhagwan and | 1234 | 0/0 | 0/0 | 0 | 0 0 | |
| Feb., Aug., Dec 1948 | Krishnan 1949 | | | | | | |
| Udaipur State M P | Subramanian and | 502 | 0/0 | 0/0 | 0 | 0 0 | |
| July Dec 1949 | Gupta 1950 | | | | | | |
| Vector species | | 33. <i>Anopheles, Sundancus, Rodenwaldt</i> | | | | | |
| North Kanara | Mhaskar 1915 | 36 | 0/0 | 0/0 | ■ | 0 0 | |
| | | 34. <i>Anopheles, Tessellatus, Theobald 1901</i> | | | | | |

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| | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------|---------|-----|-----|---|----|---|
| Cachar Assam | 6 | 0/0 | 0/0 | 0 | 00 | |
| Strickland 1929 | | | | | | |
| April Dec. 1917 | 80 | 0/0 | 0/0 | 0 | 00 | |
| Mysore | 95 | 0/0 | 0/0 | 0 | 00 | |
| Ramsay 1930 | | | | | | |
| Cachar, Assam | 9 | 0/0 | 0/0 | 0 | 00 | |
| April 1927 March 1930 | | | | | | |
| Orissa coastal plain | | | | | | |
| Senior White 1943 | | | | | | |
| 1935-1941 | 1 | 0/0 | 0/0 | 0 | 00 | |
| Jeypore Hills | | | | | | |
| Oct -1936-Sept. 1937 | 9 | 00 | 0/0 | 0 | 00 | |
| Satpura 1936-1940 | | | | | | |
| Senior White and | | | | | | |
| Adhikari 1940 | 28 | 0/0 | 0/0 | 0 | 00 | |
| Russell and Rao 1940 | | | | | | |
| Tanjore | | | | | | |
| Nov. 1936 Jan. 1940 | 18 | 0/0 | 0/0 | 0 | 00 | |
| Hazaribagh 1936-43 | 33 | 0/0 | 0/0 | 0 | 00 | |
| Ennore Nellore | (23/33) | | | | | |
| May 1937 June 1938 | 79 | 0/0 | 0/0 | 0 | 00 | |
| S Travancore | | | | | | |
| Mathew 1939 | | | | | | |
| Aug 1937-Aug. 1938 | 4 | 0/0 | 00 | 0 | 00 | |
| Bengal | | | | | | |
| Nov. 1937-Nov. 1938 | | | | | | |
| Wynnad | 113 | 0/0 | 0/0 | 0 | 00 | |
| 1918-1919 | | | | | | |
| Harbhagwan 1910 | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|----------------------|-----|-----|----------|----|------|---------------------|
| Singhbhum Hills | Senior White 1930 | 2 | 0/0 | 0/0 | 0 | 0 0 | |
| May 1938-April 1940 | Narayana | | | | | | |
| Chilka lake | Senior White 1939 | 15 | 0/0 | 0/0 | 0 | 0 0 | |
| 1939 | Adhikari | | | | | | |
| Bengal 1937 | Iyengar 1940 | 40 | 0/0 | 0/0 | 0 | 0 0 | |
| Deltaic Bengal 1939-41 | Iyengar 1940 | 11 | 0/0 | 0/0 | 0 | 0 0 | |
| Nilgiris | Russell and Jacob | 12 | 0/0 | 0/0 | 0 | 0 0 | |
| Feb, 1940-Jan, 1941 | 1942 | | | | | | |
| Waltair | Senior White and Rao | 126 | 0/0 | 0/0 | 0 | 0 0 | |
| Sept, 1940-Dec, 1941 | 1940 | | | | | | |
| North Kanara | Singh and Jacob 1944 | 239 | 0/0 | 0/0 | 0 | 0 0 | |
| May 1942-May 1943 | | | | | | | |
| Kurnool Anantpur | Rao 1946 | 33 | 0/0 | 0/0 | 0 | 0 0 | |
| Cuddapat 1942-44 | | | | | | | |
| Maldives Island 1944 | Covell 1944 | 160 | 4/2 | *2.5/1.2 | *6 | *3.7 | *Calculated figures |
| Madras Orissa coast | Senior White 1947 | 9 | 0/0 | 0/0 | 9 | 0 0 | |
| May 1944-Dec, 1945 | et al | | | | | | |
| Maldives Island | Iyengar et al 1953 | 22 | 0/1 | *0/4 5 | *1 | *4 5 | *Calculated figures |
| March 1951 | | | | | | | |
| 35. <i>Anopheles, Theobaldi, Giles, 1901</i> | | | | | | | |
| Jeypore Hills | Perry 1914 | 1/1 | 0/0 | 0/0 | 0 | 0 0 | |
| Mar.-Nov., 1912 | | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|------------------------|----------------------|-----|-----|-----|---|-----|---|
| Cochar, Assam | Ramsay 1940 | 4 | 0/0 | 0/0 | 0 | 0 0 | |
| April 1927-30 | | | | | | | |
| Singhbhum Hills | Senior White and Das | 5 | 0/0 | 0/0 | 0 | 0 0 | |
| Sept., 1935-Jan., 1937 | 1938 | | | | | | |
| Jepore Hills | Senior White 1937 | 19 | 0/0 | 0/0 | 0 | 0 0 | |
| Salpura 1936 1940 | Senior White and | 46 | 0/0 | 0/0 | 0 | 0 0 | |
| | Adhikari 1940 | | | | | | |
| Jepore Hills | Senior White 1938 | 1 | 0/0 | 0/0 | 0 | 0 0 | |
| Oct., 1936 Sept., 1937 | | | | | | | |
| Hazaribagh 1936-43 | Idem 1943 | 39 | 0/0 | 0/0 | 0 | 0 0 | |
| Poona | Barbar and Rice 1938 | 0/1 | 0/0 | 0/0 | 0 | 0 0 | |
| March July 1937 | | | | | | | |
| Singhbhum Hills | Senior White and | 3 | 0 0 | 0 0 | 0 | 0 0 | |
| May 1938-April 1940 | Narayana 1940 | | | | | | |
| Waltair | Senior White and Rao | 1 | 0 0 | 0/0 | 0 | 0 0 | |
| Sept., 1940-Dec., 1941 | 1943 | | | | | | |
| North Kanara | Singh and Jacob 1944 | 1 | 0 0 | 0 0 | 0 | 0 0 | |
| May 1942 May 1943 | | | | | | | |
| Khandwa C P | Subramanian and | 102 | 0/0 | 0/0 | 0 | 0 0 | |
| July, 1948 Jan., 1949 | Dixit 1943 | | | | | | |
| Udaipur M P. | Subramanian and | 1 | 0/0 | 0/0 | 0 | 0 0 | |
| July Dec., 1949 | Gupta 1950 | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--|--|------|-----|--------|----|------|---------------------|
| 36. <i>Anopheles, Turkhudi, Liston, 1901</i> | | | | | | | |
| Poona | Barbar and Rice 1938 | 2/10 | 0/0 | 0/0 | ■ | 0 0 | |
| March-July 1937 | | | | | | | |
| Pandharpur Bombay | Soman 1945 | 16 | 0/0 | 0/0 | 0 | 0 0 | |
| Sept., 1937-May 1938 | | | | | | | |
| Kurnool, Anantpur and Cuddapali | Rao et al 1946 | 10 | 0/0 | 0/0 | 0 | 0 0 | |
| Nasik | Bhatt 1949 | 417 | 0/1 | *0/0 2 | *1 | *0 2 | *Calculated figures |
| Oct., 1947-March 1948 | | | | | | | |
| Khandwa M P. 1948 | Subramanian and Dixit 1948 | 5 | 0/0 | 0/0 | 0 | 0 0 | |
| 37. <i>Anopheles, Umbrinus, Theobald, 1903</i> | | | | | | | |
| Jharia Bihar | Rao 1941 | 1 | 0/0 | 0/0 | ■ | 0 0 | |
| April 1938-Sept., 1940 | | | | | | | |
| Assam | Viswanathan et al 1941 | 2 | 0/0 | 0/0 | 0 | 0 0 | |
| 1940-41 | | | | | | | |
| Assam | 38 <i>Anopheles Vagus</i> Donitz, 1902 | | | | | | |
| Cachar - Assam | Chalam 1923 | 412 | 0/0 | 0/0 | 0 | 0 0 | |
| April-Dec 1927 | Strickland 1929 | 1341 | 1/0 | 0 07/0 | 1 | 0 07 | *Calculate figures |

Dissection Records

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| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|-----------------------|----------------------|-------------|-----|-------|----|------|---------------------|
| Krishnagar Bengal | Sur and Sur 1929 | 4479 | 0/0 | 0/0 | 0 | 00 | |
| Brinagar Bengal | Idem | 163 | 0/0 | 0/0 | 0 | 00 | |
| Vizagapatnam Madras | Venkataraman 1929 | 50 | 0/0 | 00 | 0 | 00 | |
| Mysoore | Sweet 1929-30 | 903 | 0/0 | 0/0 | 0 | 00 | |
| Cachar Assam | Ramsay 1930 | 7601 | 0/0 | 0/0 | 0 | 00 | *Calculated figures |
| April 1927-March 1930 | | 249 | 0/0 | 0/0 | 0 | 00 | |
| Jorhat Assam | Ramsay 1931 | 10452 | 0/2 | 0/001 | *2 | *001 | *Calculated figures |
| Assam | Strickland | 137 | 0/0 | 0/0 | 0 | 00 | |
| W. Bengal (1933 40) | et al 1933 | 6874 | 0/0 | 0/008 | 1 | 001 | |
| Tanjore | Sen 1948 | (6247/6781) | 0/0 | 0/0 | 0 | 00 | |
| Nov 1936-Jan 1940 | Russel and Rao 1940 | 12133 | 0/0 | 0/0 | 0 | 00 | |
| Poona | Barbar and Ruce 1938 | 697 | 0/0 | 0/0 | 0 | 00 | *Calculated figures |
| March to July 1937 | Iyengar 1939 | 63 | 0/0 | 0/0 | 0 | 003 | |
| Bengal | Roy 1939 | 3151 | 0/1 | 0/008 | 1 | | |
| Nov 1937-38 Nov | Russell et al 1939 | (3103/3149) | | | | | |
| Bally Calcutta | | | | | | | |
| Aug 1937 July 1938 | | | | | | | |
| Ennore, Nellore | | | | | | | |
| Pattu kotal | | | | | | | |
| Jan 1937 March | | | | | | | |
| July 1937 | | | | | | | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------------------|--------------------------|---------|-----|-----|---|-----|---|
| Ennore Nellore | Russle <i>et al</i> 1939 | 26 | 0/0 | 0 0 | 0 | 0 0 | |
| May | | (24/26) | | | | | |
| Pandharpur Bombay | Soman 1945 | 1 | 0/0 | 3/0 | ■ | 0 0 | |
| Sept 1937 May 1938 | | | | | | | |
| Darjeeling | Gilroy 1939 | 16 | 0/0 | 0/0 | 0 | 0 0 | |
| June Nov 1938 | | | | | | | |
| Wynaad | Covell and Harbhagwan | 561 | 0 0 | 0/0 | 0 | 0 0 | |
| 1938 1939 | 1939 | | | | | | |
| Jharia Bihar | Rao 1941 | 1843 | 0/0 | 0/0 | 0 | 0 0 | |
| April 1938 Sept 1940 | | | | | | | |
| Deltaic Bengal | Iyengar 1944 | 2607 | 0/0 | 0/0 | 0 | 0 0 | |
| 1939 41 | | | | | | | |
| Assam | Vishwanathan 1941 | 3396 | 0/0 | 0/0 | ■ | 0 0 | |
| 1940 41 | | | | | | | |
| Nilgiris | Russel and Jacob 1942 | 464 | 0/0 | c/o | 0 | 0 0 | |
| Feb 1940-Jan 1941 | | | | | | | |
| Nizamabad | Abraham and Samuels | 11 | 0/0 | 0/0 | 0 | 0 0 | |
| 1940 1942 | 1944 | | | | | | |
| Darjeeling 1941 | Khan 1942 | 475 | 0/0 | 0/0 | 0 | 0 0 | |
| Uda pur C P | Roy and Biswas 1942 | 41 | 0/0 | 0/0 | ■ | 0 0 | |
| Aug Nov 1941 | | | | | | | |
| North Kanara 1944 | S ngh and Jacob 1944 | 796 | 0/0 | 0/0 | 0 | 0 0 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|----------------------|--------------------------|---------|-----|-----|---|----|---|
| Ennore Nellore | Russle <i>et al</i> 1939 | 26 | 0/0 | 0/0 | ■ | 00 | |
| May | | (24/26) | | | | | |
| Pandharpur Bombay | Soman 1945 | 1 | 0/0 | 3/0 | ■ | 00 | |
| Sept 1937-May 1938 | | | | | | | |
| Darjeeling | Gilroy 1939 | 16 | 0/0 | 0/0 | 0 | 00 | |
| June-Nov 1938 | | | | | | | |
| Wynad | Covell and Harbhagwan | 561 | 00 | 0/0 | 0 | 00 | |
| 1938-1939 | 1939 | | | | | | |
| Jharia Bihar | Rao 1941 | 1843 | 0/0 | 0/0 | 0 | 00 | |
| April 1938 Sept 1940 | | | | | | | |
| Deltac Bengal | Iyengar 1944 | 2607 | 0/0 | 0/0 | 0 | 00 | |
| 1939 41 | | | | | | | |
| Assam | Vishwanathan 1941 | 3396 | 0/0 | 0/0 | ■ | 00 | |
| 1940-41 | | | | | | | |
| Nilgiris | Russel and Jacob 1942 | 464 | 0/0 | c/o | ■ | 00 | |
| Feb 1940-Jan 1941 | | | | | | | |
| Nizamabad | Abraham and Samuels | 11 | 0/0 | 0/0 | ■ | 00 | |
| 1940 1942 | 1944 | | | | | | |
| Darjeeling 1941 | Khan 1942 | 475 | 0/0 | 0/0 | ■ | 00 | |
| Udaipur C P | Roy and Biswas 1942 | 41 | 0/0 | 0/0 | 0 | 00 | |
| Aug-Nov 1941 | | | | | | | |
| North Kanara 1944 | Singh and Jacob 1944 | 796 | 0/0 | 0/0 | 0 | 00 | |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|--|-----|-----|-----|---|-----|---|
| Kurnool, Anantpur Cuddapah. | Rao <i>et al</i> 1946 | 65 | o/o | o/o | o | o o | |
| Damodar-Hoogly basin | Jafer <i>et al.</i> 1947 | 110 | o/o | o/o | o | o o | |
| Nellore | Raghawan and Krishnan 1949 | 407 | o/o | o/o | o | o o | |
| Feb-Aug-Dec 1948 Udaipur M P. July-Dec 1949 | Subramanian and Gupta 1950 | 54 | o/o | o/o | o | o o | |
| Vector Species | 39 <i>Anopheles Varuna</i> Iyenger, 1924 | | | | | | |

REFERENCES

- Abraham A C and Samuels, R D (1944) Epidemiology of malaria in the Nizam Sagar Ayaent Area, Nizamabad district Hyderabad State.
- Adie, J R (1905) *J Mal Inst Ind* 5, p 305 318 Mosquitoes and Malaria in Ferozepur Distt *Ind Med Gaz* 40, 5 12
- Anderson L A P and Vishwa Nathan, D K (1941) The Assam Medical Research Society A resume of its activities during 1931-41 *Mal rept Assam*
- Banerjee, A C (1930) Some observations on an unusual epidemic of malaria in the city of Lucknow *Ind Med Gaz* 65, p 149 153
- Barber M A and Rice, J B (1938) Malaria in Poona and in its vicinity *J Mal Inst Ind* 1, p 37
- Bhatt, H R (1949) A note on a natural occurrence of sporozoites of *Plasmodium* in *Anopheles turkhudlestoni*. *Ind J Mal* 3, p 109 110
- Bose, K (1931) Mosquito survey of Bir Nagar *Rec Mal Surv Ind* 2 p 193 224
- Chalam B b. (1923) Some notes on a malaria investigation on a sugar estate in Kumrup Assam *Ind Med Gaz Oct. 1923, p. 476 79*
- Clyde, D (1931) Report on the control of malaria during the Sarda Canal Constructions (1920-29) *Rec Mal Surv Ind* 2, p 49 110
- Covell G (1927) Transmission of malaria by *Anopheles* A critical review *Ind Med Res Mem* 7, p 1 117
- Idem* (1931) The present state of our knowledge regarding the transmission of malaria by the different species of anopheline mosquitoes *Rec Mal Surv Ind* 2 p 1 48
- Idem* (1944) Notes on the distribution breeding places, adults habits relation to malaria of anopheline mosquitoes of India and far east *J Mal Inst* 5 p 399 434
- Covell G and Harbhagwan, J (1939) Malaria in Wynaad, S India *J Mal Inst Ind* 2, p 341 376
- Covell, G and Singh P (1942) Malaria in nui belt coastal belt of Orissa *J Mal Inst Ind* 4, p 457 593

Dissection Records

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Das, B K

Fry, A B

Gill, C A

Gilroy, A

Graham, J D

Idem

Idem

Hodgson E C

Horsfall, W R

Iyengar, M A R

Iyengar, M O T

Idem,

Idem

Iyengar, M O T, Mathen

M I and Menon M A U

Jaffer M and Iyengar M O T

James S P

Kenrick, W H

(1942) Malaria in Chandpur (Bengal) *Ind Med Gaz* 78 p 327 330.

(1914) The report on malaria in Bengal Beng Sect Book Depot, Calcutta

(1917) Report on malaria in Amritsar Oct. 1913 Oct 1914 Govt. Press Lahore

(1939) Health in tea gardens of the Darjeeling terai with special reference to malaria *J Mal Inst* 22 p 165 179

(1910a) Report on an enquiry into the prevalence of malaria in Kosi, Distt Muttra Govt Press Allahabad

(1910b) An enquiry into the prevalence of malaria in Kosi (Distt Muzaffar Nagar) 1910 Govt Press, Allahabad

(1913) Report on an enquiry into the prevalence of malaria in Meerut 1911 Govt Press Allahabad

(1914) Malaria in the new province of Delhi, *Ind J Med Res* 2 p 405 455

(1955) Mosquitoes their bionomics and relation to disease The Ronald Press Company New York

(1927) Unpublished Report by Covell 1931

(1939) A years work on dissection of Anopheles for natural malarial infection. *J Mal Inst* 2, p 105 109

(1940) Further observations on vectors of Malaria in Bengal *J Mal Inst* Ind 3, p 115 123

(1944) Problems relating to malaria control in Deltaic Bengal *J Mal Inst* Ind 5 p 435 447

(1953) Malaria in Maldiv Islands *Ind J Mal* 7 p 1

(1947) The incidence of malaria in a Deltaic area of lower Bengal between the Damodar and the Hooghly rivers *Ind J Mal.* 1, p 441 467

(1902) Malaria in India Section Govt India VI Govt Press Calcutta

(1914) Report upon Malaria in Central Provinces 1912 13. Govt Press, Nagpur

- Senior White, R and Das, B K (1938) On malaria transmission in the Singhbhum Hills *J Mal Inst*, 1, p 169 184
- Senior White R and Ghosh, A R (1946) House spraying with DDT Further results *J Mal Inst Ind*, 6 p 489 508
- Senior White R and Narayana P A (1940) On malaria transmission in the Singhbhum Hills *J Mal Inst Ind*, 3, p 413 425
- Senior White, R and Rao, V V (1943) On malaria transmission around Vizagapatnam *J Mal Inst Ind*, 5 p 187 205
- Senior White, R Adhikari A K and Ramakrishnan, V, Roy, B B (1943) On malaria transmission on the Orissa Coastal Plain *J Mal Inst Ind*, 5, p 159 186
- Senior White, R Ghosh, A R (1943) On the adult bionomics of some Indian anophelines with special reference to malaria control by Pyrethrum spraying *J Mal Inst Ind*, 6 p. 129 215
- Senior White, R Ramakrishna V and Rao V V (1947) Malaria on the North Madras Coast *Ind J Mal Ind*, p 81 109
- Shortt H E (1924) The occurrence of malaria in a Hill Station *Ind J Med Res* 11 p 77 789
- Singh J and Jacob, V P (1944) Malaria investigation in North Kanara *J Mal Inst Ind*, 5 p 267 303
- Soman D N (1945) Malaria in Pandharpur, Bombay Presidency *J Mal Inst Ind*, 6 pp 99
- Stephenson and Christopher, S R (1902a) Relation of malarial endemicity to species of Anopheline *Rept Mal Comm Roy Soc Series*, 6 p 3 10.
- Idem* (1902b) The relation of species of Anopheline to Malaria endemicity *Rept Mal Comm Roy Soc Series*, 7, p 15 23
- Strickland C (1929) The relative malarial infectivity of some species of anophelines in Cachar, Assam *Ind J Med Res*, 17 p 174 182
- Strickland C, Choudhury, K C and Choudhury, H P (1931) The sporozoites rate of anophelines caught wild in the terai 1931 *Ind J Med Res*, 15 p 67 89
- Subramanian, R and Dixit, D T (1948) Observations on the vectors of malaria in Khandwar tehsil, Nimar district, Central Provinces and notes on the seasonal infectivity of anophelines *Ind J Mal*, 2, p 313 322

- Subramanian R and Gupta R K S (1950) Malaria transmission in former Udaipur State, Central Provice *Ind J Mal* 4 p 91-96
- Sur, S N and Sur, P (1929) Report of the Bengal Field Malaria Research Krishnagar Laboratory 1926-28 Govt of Bengal P H D Calcutta
- Timbers H S (1935) Studies on malaria in villages in Western Bengal *Rec Mal Surv Ind* 5 p. 345
- Venkataraman K V (1929) A report on malaria in Vizagapatam Supp to ann report King Instt Gundy 1927-28 p 37-41
- Vishwanathan D K, Das S and Chatterjee A V (1941) Malaria carrying anophelines in Assam *J Mal Inst Ind* 4 p 297-306

